METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

MARCH, 1954 Vol. XLIX. No. 293

Technical Societies

THE last hundred years have seen an enormous increase in the number of technical societies in this country—an increase which has, on the whole, been steady, each decade adding to the total. Some of them have been established to cater for new technical developments, as in the case of the radio and electronic fields, others to deal more thoroughly with sectional aspects of a subject than was possible within the confines of the parent society. More recently, the latter problem has been tackled by the formation of specialist groups within the parent body, as witness the Corrosion Group of the Society of Chemical Industry and the Engineers Group of the Iron and Steel Institute.

The Institute of British Foundrymen, the Iron and Steel Institute, the Institute of Metals, and the Institution of Mining and Metallurgy have all been in existence for a long time, and although certain societies fairly closely linked with metallurgy such as the Institute of Welding have been established more recently, the only purely metallurgical newcomer is the Institution of Metallurgists, which was set up shortly after the war. As, however, the Institution is a qualifying rather than a publishing body, it would be more proper to regard it as a professional association than as a technical society. Whilst the Institution is concerned with the improvement of the status of metallurgy as a profession, the main function of the other societies is the publishing of such technical papers as are deemed to represent an addition to the store of metallurgical knowledge, and the organising of meetings for the discussion of such papers.

It is evident, therefore, that the primary purpose of these bodies—and of similar organisations in other fields—is an educational one. This point was considered at some length by Mr. E. J. Dunstan in his Chairman's Address to the Manchester Section of the Society of Chemical Industry, when he discussed the future of technical societies. Mr. Dunstan called attention to the fact that, with the present all-embracing educational system, the state provides facilities from the age of five (three in some cases) to the early twenties—from the nursery or primary school to the university—and there, in the main, it stops. Maybe it is felt that by the time a man has completed his university training he should be capable of educating himself. It is at this stage that the technical societies take over and provide for that further education, of graduate and non-graduate alike, which is so essential if technical progress is to continue.

Before the war, the national societies were able, for a reasonably moderate subscription, to provide their members with preprints of all papers accepted for publication, in addition to the bound volume containing a report of the discussion of the papers presented at meetings of the society, and abstracts from current technical literature. The rapid rise in costs which occurred immediately after the war, together with the increase in the output of technical work worthy of publication, created financial problems for the national societies, because the greatly swollen publication costs made it difficult to balance the budget, in spite of increased subscriptions and revenue from advertisements appearing in the official publications. Although paper costs have fallen slightly, the cost of printing remains high, and with increasing demands on the editorial pages of the societies' journals, the long-term financial situation cannot but be a matter for concern. In some cases industry has helped to buffer the worst of the increased costs, but this cannot be regarded as a permanent feature. An increased membership would undoubtedly help matters, but with the present high cost of living, prospective members feel the need to think twice before committing themselves to further annually recurring expenditure.

Mr. Dunstan put forward the suggestion that, as the technical societies were making themselves reponsible for the further education of scientists and technologists, to the importance of whom, both in regard to quality and quantity, frequent lip-service has been made by Government spokemen, the state should assist them financially. No doubt, the presence of Government representatives on the governing body would hardly be welcome but such an argument has not been put forward for the abolition of the University Grants Committee. Perhaps a better way would be to make subscriptions to approved technical societies eligible for 100% tax relief, and thus minimise one of the obstacles to increased membership.

It would not be fair to give the impression that the service given by the national societies has deteriorated: on the contrary, it has improved in many ways. Nevertheless, income and expenditure have to be more carefully watched than was formerly the case. This is a problem which faces local societies too, as costs of hiring rooms take an upward trend, and a : printing, stationery and postages, even in societies which do not publish any record of their proceedings, represent a very heavy item of expenditure. Here again, the coat must be cut according to the cloth, or the society must get a bigger piece of cloth by increasing the subscription. There are several possible ways of economising: less costly and probably less suitable premises; fewer circulars; or fewer meetings. Each represents a deterioration in the service a society gives to its members, however, and the net result might be an aggravation of the situation by reducing the membership.

The technical societies, whether local or national, are playing an important part in the technological progress of this country, and to that extent the state has good reason to see that they do not fade away. They are, too, invaluable to the technologist in providing a forum for the discussion of the latest developments, and for the exchange of ideas: it is up to him to see that they flourish with his support.

April Diary

1st

Institute of Metals—London Local Section. Annual General Meeting, followed by Discussion on "The Brittle Fracture of Metals." Opening Speakers: Dr. L. Northcott on "Molybdenum," Dr A. H. Sully on "Manganese and Chromium," and Dr. A. A. Wells on "Theoretical Aspects." 4, Grosvenor Gardens, London, S.W.1. 6 p.m.

Leeds Metallurgical Society. "Bearings and Bearing Alloys," by R. T. Rolfe. Chemistry Department, The University, Leeds, 2. 7-15 p.m.

2nd

Institute of Fuel—South Wales Section. "Total Gasification of Coal," by Dr. F. J. Dent. South Wales Institute of Engineers, Park Place, Cardiff. 6 p.m.

5th

Institute of British Foundrymen (Sheffield & District Branch). "The Use of Feeding Materials," by D. H. Snelson. Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield, 1. 7-30 p.m.

6th

East Midlands Metallurgical Society. Annual General Meeting followed by "Wire Drawing," by R. S. Brown. Nottingham and District Technical College, Shakespeare Street, Nottingham. 7-30 p.m.

Institution of Works Managers (Sheffield Branch). "Production Planning and Control—American Methods," by T. Greenlees. Joint Meeting with Institute of Industrial Supervisors. Grand Hotel, Sheffield. 7-30 p.m.

Sheffield Metallurgical Association. "Preparation of the British Chemical Standards," by N. D. and P. D. Ridsdale. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

8th

Liverpool Metallurgical Society. Annual General Meeting, followed by "The Cold Working of Metals," by J. G. Wistreich. Joint Meeting with the Iron & Steel Institute and the North Wales Metallurgical Society. Liverpool Engineering Society, The Temple, Dale Street, Liverpool. 7 p.m.

9th

Institute of Fuel—Scottish Section. Annual General Meeting, followed by "High-temperature Heating Fluids," by C. M. Auty. Royal Technical College, Glasgow. 7 p.m.

Institution of Mechanical Engineers "The Observation and Control of Dust at Pneumatic Chisels" and "The Observation tion and Control of Dust at Portable Grinding Wheels," by W. B. Lawrie, A. T. Holman, O.B.E., and E. B. James. Storey's Gate, St. James's Park, London, S.W.1. 5-30 p.m.

West of Scotland Iron & Steel Institute. Annual General Meeting. "Bright Drawing and Bright Turning of Steel Bars," by R. Russell, J. Gillespie and A. Fisher. 39, Elmbank. Crescent, Glasgow. 6-45 p.m.

12th

Junior Institution of Engineers (Sheffield & District Section). "Choosing and Using Special Steels," by A. V. Jobling. Livesey Clegg House (opposite Union Street Cinema) Sheffield. 7-30 p.m.

Institute of Fuel—North Eastern Section. "Atomic Energy," by R. V. Moore. Chemistry Lecture Theatre, King's. College, Newcastle-upon-Tyne. 6-30 p.m.

13th

Institute of British Foundrymen—East Anglian Section. Annual General Meeting. "Operating Experiences with Hot Blast Cupolas in Great Britain," by F. C. Evans. Central Hall, Public Library, Ipswich. 7-30 p.m.

Institution of Engineers and Shipbuilders in Scotland. Annual General Meeting. "Investigations on Surface Finish of Steel Shafts," by Prof. A. S. T. Thomson, Prof. A. W. Scott, W. Ferguson and G. V. Stabler. 39, Elmbank Crescent, Glasgow. 6-45 p.m.

Sheffield Metallurgical Association. "Powder Metallurgy as an Aid to Production," by G. R. Bell. B.I.S.R.A., Hoyle Street, Sheffield. 7 p.m.

14th

Institute of Welding—West of Scotland Branch. Annual General Meeting, also "Some Recent Developments in the Welding of Aluminium Alloys and their Future Applications to the Shipbuilding Industry," by F. St. M. Brierly and J. E. Tomlison. 39, Elmbank Crescent, Glasgow, C. 2. 7 p.m.

19th

Institute of Welding (Sheffield & District Branch). Annual General Meeting. Sheffield College of Commerce and Technology, Pond Street, Sheffield, 1. 7.15 p.m.

Sheffield Society of Engineers and Metallurgists. Film Evening. University Building, St. George's Square, Sheffield. 7.30 p.m.

22nd

Institute of British Foundrymen—Southampton Section. Annual General Meeting. "Methods Employed in the Production of Heavy Iron Castings," by J. Richardson and C. F. Lawson. Southampton Technical College, St. Mary Street, Southampton. 7 p.m.

23rd

North East Coast Institution of Engineers and Shipbuilders. "Some Practical Effects of Tip Clearance in Turbine Blading," by J. L. Jefferson. Mining Institute, Newcastle-upon-Tyne. 6-15 p.m.

26th

Institute of Metals. Annual May Lecture. Royal Institution, Albemarle Street, London, W.1. 6 p.m.

Institution of Production Engineers (Sheffield Graduate Section). "Some Aspects of Working Methods," by A.B. Armstrong. Sheffield College of Commerce and Technology, Department of Engineering, Pond Street, Sheffield, 1. 7 p.m.

North East Metallurgical Society. "The Properties and Applications of Spheroidal Graphite Iron," by Dr. A. B. Everest. Cleveland Scientific and Technical Institution, Middlesbrough. 7-15 p.m.

26th–29th

Institute of Metals. Spring Meeting, London. (Joint. Meeting with the Société Française de Métallurgie). 4, Grosvenor Gardens, London, S.W.1.

27th

Institute of Metals. Annual General Meeting. Presidential Address, by Dr. S. F. Dorey, C.B.E., F.R.S. Discussion of Papers. 4, Grosvenor Gardens, London, S.W.1.

28th

Institute of British Foundrymen—London Branch. Annual General Meeting, followed by film on "Dust Extraction." Waldorf Hotel, London, W.C.2. 7 p.m.

Institute of Metals. All-day Symposium on "Control of Quality in the Production of Wrought Non-Ferrous Metals, II—The Control of Quality in Working Operations." Discussion of Papers. 4, Grosvenor Gardens, London, S.W.1.

29th

Institute of Metals. Informal Discussion on "Recovery and Recrystallisation." Visits to Works and Laboratories. Dinner-Dance.

30th

Incorporated Plant Engineers—Birmingham Branch. "Welding," by F. A. Thomas. Imperial Hotel, Birmingham. 7-30 p.m.

Institution of Mechanical Engineers. "Nodular Cast Iron—its Present Position and Future Prospects as an Engineering Material, with Special Reference to its Suitability for Crankshafts," by S. B. Bailey. Storey's Gate, St. James's Park, London, S.W.1. 5-30 p.m.

30th April to 5th May

Institute of Metals. Visits in London and the Provinces arranged for members of the Société Française de Métallurgie

Plane Plasticity*

By B. B. Hundy, Ph.D., B.Sc.†

Some of the fundamental ideas of the theory of plasticity are presented as a basis for the understanding of the more useful parts of the theory. The second part of the paper is devoted to experimental work, checking a number of theoretical predictions of deformation behaviour. Excellent agreement between theory and practice is obtained in nearly all cases.

THE late war stimulated research into the mathematical theory of plasticity, which has since advanced so rapidly that only specialists in the field can keep abreast of the latest developments. Many parts of the theory, however, are applicable to technological problems, and it is obviously desirable that scientists working in related fields should have some idea of its nature and scope. The object of the first part of this paper, however, is not to teach plasticity, but rather to present some of the basic ideas, so that an engineer or metallurgist can understand the more useful parts of the theory. The second part of the paper describes experiments confirming results predicted by theory.

PART I.—AN OUTLINE OF THE THEORY

In general, the theory of plasticity has two main objects :—

(1) To predict the manner of deformation and the forces involved in metal working operations. If these can be estimated accurately, then the operation can be so designed as to be carried out in the most efficient way, and more effective control of the process is possible.

(2) To predict the maximum load that can be applied to a body without causing yielding.

The essential difference between these two objects is that in the first case the theory is concerned with large plastic deformations, such as arise in rolling, sheet drawing, extrusion, etc.,[1,2] while in the second case only the initial yielding is of interest. One of the most important applications of this latter aspect of the theory lies in establishing realistic safety factors for structural design,[3] so that designs can be based on the yield-point load rather than on the ultimate tensile strength.

Most theoretical solutions have been obtained for deformation under plane conditions, that is, when no strains are present in the transverse direction (plane strain) or when no stresses act perpendicularly to the plane in a thin sheet (plane stress). Some approximate theories for axially symmetrical problems, such as wire drawing or extrusion, have been put forward[4], but the general methods for obtaining complete solutions have not yet been worked out. However, solutions to the simpler axi-symmetric problems of the deep drawing of cups and of tube drawing have been obtained,[5,6] which give reasonable agreement with experimental practice. When the problem is too difficult for exact solution, a rough guide to the deformation, and to the forces required, can sometimes be obtained by consideration of the analogous plane strain problem, e.g., rod and strip extrusion.

It is often not easy to obtain complete solutions to even the simpler problems of plane plastic deformation, as there are so many different factors involved. The relation between stress and strain in a deforming body is not usually simple and, moreover, it is not a constant for a given metal, but depends on the treatment previously given to that metal. A complete solution to any problem would have to allow for the elastic deformations as well as the plastic ones, and would also have to consider the work-hardening taking place during the deformation, as well as any change of shape of the body. These considerations make the mathematical solution extremely difficult, if not impossible, to attain, and a number of assumptions are usually made, to enable solutions to be obtained more easily. These are discussed in the following section.

Assumptions of the Theory

The actual assumptions made depend on the problem in question, but the following are the more usual ones.

(1) That the metal being deformed is a continuous medium. The main implication of this assumption is that a real metal can be considered as a continuous medium only if the grain size is small compared with the size of the body and, in point of fact, only if it is a pure metal or a single phase alloy.

(2) That the metal is isotropic. As a metal is crystalline in nature, any deformation will tend to lead to preferred orientation, and the assumption that the mechanical properties are the same in any direction is not strictly justified. However, it is only after comparatively severe deformation that preferred orientation becomes really pronounced and, on the whole, it is a reasonable approximation to consider the metal as isotropic.

(3) That the metal is a plastic-rigid material. This means that in the calculations all the elastic deformations are ignored. The metal is assumed to remain perfectly rigid up to a certain stress, and then to become plastic. Thus, a region of plastically deforming metal is separated from a region of rigid metal by a sharp boundary. This assumption of a plastic-rigid body is justified if the elastic strains are very small compared with the plastic strains and often in cases of initial yielding. In cases where they are of the same order it is not always warranted, and the calculations must then be based on a plastic-elastic body. The technique of solution in this case is usually rather complex and only a few such problems have been studied.[7,8,9]

(4) That the metal does not work-harden. In problems concerned only with the initial yielding, the subsequent work-hardening is not important and can

* Paper MW/B/5/54 of the Solid Mechanics Group of the Mechanical Working Division of The British Iron & Steel Research Association. The views expressed are the author's and are not necessarily endorsed by the Group as a body.

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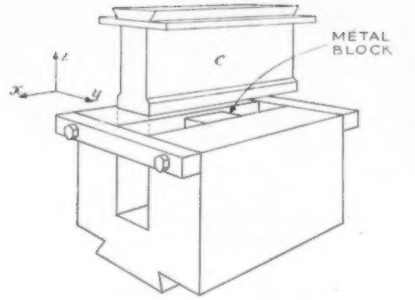
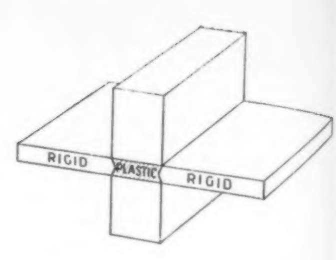


Fig. 1 (left).—Two dimensional (plane strain) compression.

Fig. 2 (right).—Plane strain indentation by flat tools.



be ignored. If, however, the problem involves severe plastic deformation, it is obvious that some allowance must be made for work-hardening of the metal, or the calculations will underestimate the forces required for deformation. Some materials, such as lead and most cold-worked metals, do not work-harden appreciably and these can be used to confirm experimentally the accuracy of a given solution. Such a solution is usually corrected for the work-hardening which takes place in most metals by selecting some mean value for the yield stress.

Although assumptions such as those given above have to be made, it has been found that the theory predicts very closely the actual behaviour of a real metal, and it can be used with some confidence.

Plane Strain Plasticity Theory

Plane strain conditions are said to exist when the cross section of the deforming body is uniform in one direction, and the strain in this direction is zero. Deformation usually leads to flow in all directions, and it is only by applying a constraint that the flow of metal can be made two-dimensional. This constraint can either be applied artificially, by external lubricated fixed blocks, such as the walls of the die in the two-dimensional compression shown in Fig. 1, or it can arise naturally from the specimen itself, as in the example shown in Fig. 2, where the rigid parts outside the deforming region prevent any appreciable transverse spread. Typical examples found in practice of deformation under approximately plane strain conditions, include rolling, strip drawing, certain machining operations and notch-bend tests with wide specimens.

It was pointed out in the previous section that some parts of a deforming plastic-rigid body are plastic and others are rigid. Attention will be confined to the plastic region, where the state of stress generally varies from point to point. The stress in the plane of deformation at any point can always be expressed as a combination of normal stress (σ_x and σ_y) and shear stresses (τ_{xy}). For instance, Fig. 3*a* shows the stresses acting on a small square element of the material, the value of the stresses depending on the orientation of the element. There is always an orientation for which the shear stresses are zero, i.e., $\tau_{xy} = 0$ and the normal stresses σ_x and σ_y are then called the principal stresses (Fig. 3*b*). At 45° to this orientation, the shear stresses are a maximum, $\tau_{xy} = k$ say, and the corresponding stresses σ_x and σ_y are equal (to p in Fig. 3*c*). k is related to the yield stress of the metal, and is a constant in plane strain, since it is assumed that no work-hardening takes place. Although k is constant throughout the deforming region, p varies from point to point, and it is only possible to calculate the external loads needed to cause deformation if the variation in p throughout the plastic region is known.

The solution to a problem in plane strain is obtained by constructing a field called the slip-line field. These slip-lines are not the surface markings visible under a microscope, but are lines parallel to the directions of maximum shear stress in the plastic region. The slip-line field is constructed to cover the region of the body that is deforming plastically. As can be seen in Fig. 3*c*, there are two directions in which the slip-line can be parallel to the direction of maximum shear stress, and the slip-line field consists of a network of orthogonal lines spaced at convenient intervals. The slip-lines are also directions of zero strain rate, i.e., there is no change in length along these lines. A typical slip-line field, for the indentation by a narrow tool of a block of metal resting on a smooth base,[2] is shown in Fig. 4 (this diagram represents a cross section through the specimen in the plane of flow). Once the slip-line field is constructed, the value of p can be calculated at any point in the plastic region, and the external loads and deformation can be found.

The slip-line field gives the instantaneous state of yielding. This is all that is needed in a problem of initial yielding, but if deformation proceeds, the shape of the body usually changes and so, therefore, does the slip-line field solution. Usually it is only possible to obtain a solution for the initial yielding, and the solution cannot be continued as it is not generally possible to follow the change of shape of the body. However, in certain continuous forming processes, such as rolling, drawing and extrusion, the shape of the deforming region is controlled by the shape of the working tools and remains constant. In such problems, it is possible to obtain slip-line field solutions which involve very severe deformations. A slip-line field which has been obtained for strip-drawing[2] is shown in Fig. 5.

When it is not possible to determine the complete slip-line field solution, approximations to the applied load can sometimes be obtained from certain kinds of incomplete solution.[10, 11]

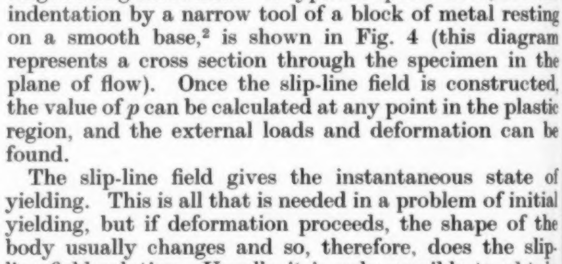


Fig. 3.—Stresses on a small element deformed under conditions of plane strain: (a) general case; (b) shear stress zero; (c) shear stress maximum. α - α and β - β are directions of maximum shear stress (slip lines).

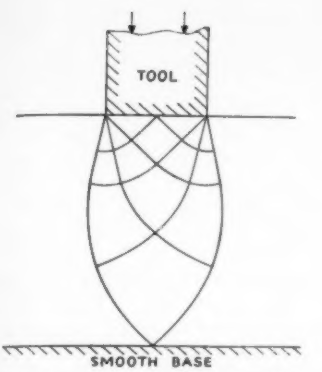


Fig. 4.—Slip-line field for the indentation by a single tool of a block of metal resting on a smooth base (after Hill).

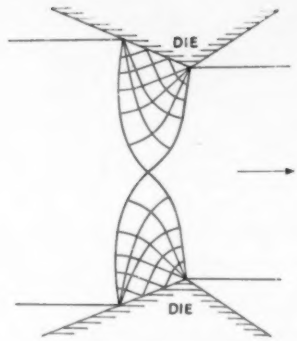
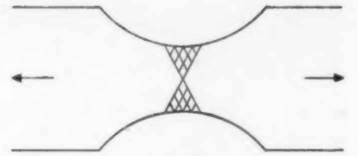
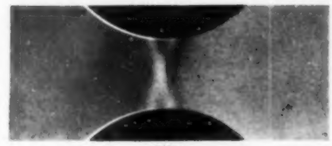


Fig. 5.—Slip-line field for the drawing of strip through a smooth die (after Hill).



(6a)



(6b)

Fig. 6.—Yielding in notched strip (plane stress conditions): (a) theoretical characteristic field (after Hill); (b) necking in a copper specimen.

Plane Stress Plasticity Theory

The second plane condition that enables exact solutions to be obtained is that of plane stress.[2] The formal definition is that a state of stress is plane with respect to Cartesian axes (x, y) when the stress components σ_z, τ_{zx}, τ_{yz} in the z direction are zero. This simply means that the stresses in a thin sheet of metal must act only in the plane of the sheet, and that they must be uniform throughout its thickness. These conditions apply in practice when the metal sheet is very thin compared with its other dimensions. Typical practical problems that come under the heading of plane stress include the yielding of thin structural members and localised necking and failure in sheet metal working.

The method of solution of a plane stress problem is similar to that in plane strain, in that a field is constructed to cover the deforming plastic region, and once the geometry of this field is known, it is possible to calculate the working loads and the manner of deformation. As in plane strain, the two families of lines which make up the field are directions of zero strain rate (no extension along the lines) and are called characteristics. However, they are not generally orthogonal, nor are they necessarily directions of maximum shear stress.

Failure in sheet metal working operations often occurs by localised necking, and plane stress theory predicts the position of the neck (along one or more characteristics) and the load at which necking commences.[12] A typical plane stress characteristic field for the yielding of a thin strip notched in its plane is shown in Fig. 6*a*, and Fig. 6*b* shows the mode of necking in copper strip notched in a similar manner. The agreement between theory and practice is qualitatively good.

PART II.—EXPERIMENTAL CONFIRMATION OF THE THEORY

The application of theoretical solutions to the better design of equipment and to improving efficiency is obvious, but it is essential that we should know just how good the theory is. For this reason, constant experimental checks have to be made as the theory progresses, and it is the object of this part of the paper to show how these checks are made, and also to show that the experiments closely confirm the theory.

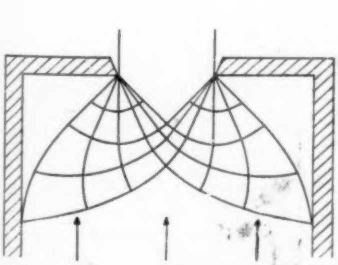
Two methods of approach can be used to check whether a theoretical solution of a problem is correct or not. One is to measure the applied loads and to compare them with those predicted by theory, and the other is to compare the theoretical and actual patterns of deformation. Both methods have been used at B.I.S.R.A., but the second one more frequently, as it has been found to be the simpler technique of the two.

Comparison of the Mode of Deformation

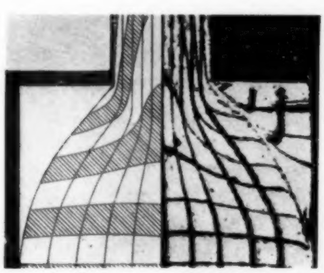
1. *Continuous Forming Processes.*

The usual method of studying the mode of deformation in a process such as drawing or extrusion, is to section down the centre, the specimen being tested, and then to scribe a square grid on one of the inner faces, before fastening the halves together and working. The manner in which the previously square grid is deformed gives an indication of the mode of deformation during the working process. If the deformation were perfectly homogeneous as in, for example, frictionless compression, each square of the grid would deform to a rectangle. However, the deformation is usually not homogeneous, and in this case the squares deform to parallelograms or similar shapes.

In plane strain, the deformation of a square grid as it passes through a slip-line field can be worked out theoretically and can then be compared with the deformation of the grid as observed in practice. This technique has frequently been applied to metal specimens, but it has often proved

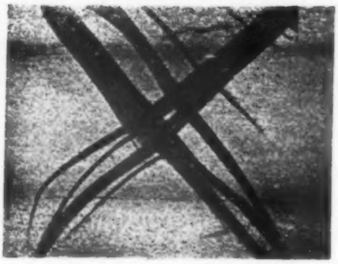


(7a)

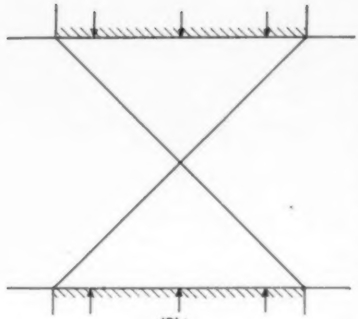


(7b) (7c)

Fig. 7.—Plane strain extrusion from a rough container: (a) slip-line field; (b) predicted deformation of a square grid; (c) deformation of a square grid on a plasticine pattern.



(8a)



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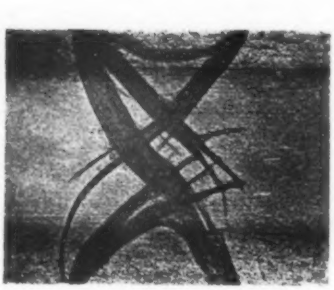

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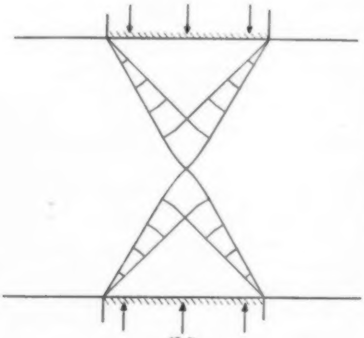


(8d)

Fig. 8.—Indentation of a specimen from both sides with flat lubricated tools : (a) etched deformation pattern (t/b=1) ; (b) theoretical slip-line field (t/b=1) ; (c) etched deformation pattern (t/b=1·6) ; (d) theoretical slip-line field (t/b=1·6).

convenient to use plasticine instead of metal. Plasticine behaves in a very similar manner to an ideal metal,[13] and has the great advantage that the specimens are easy to prepare. The usual technique is to make the specimen in two halves (it can easily be cut to shape with fine wire in a fretsaw frame), and then to stamp the grid in ink on one inside face. The two halves are then placed together and the composite specimen is deformed between lubricated metal plates, so as to ensure plane strain conditions. Fig. 7 compares the deformation of the grid on a plasticine specimen extruded in a rough container (lined with emery paper) with the theoretically predicted grid deformation and the slip-line field. The agreement is very close, and Purchase and Tupper[14] have found equally good agreement during the extrusion of lead. It should be possible to work backwards from observed grid deformations and obtain an otherwise unknown slip-line field, but the work involved would be very tedious and no attempt at this has yet been made.

In this connection, it is interesting to note that there are a number of experimental observations of grid deformations in the literature,[15, 16, 17] but so far, exact solutions have not been obtained for these particular working processes (rolling, wire drawing, etc.).

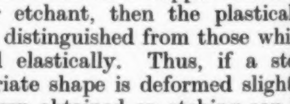
2. *Initial Yielding.*

The plastic deformations involved in initial yielding problems are rather small, and the method of confirmation outlined above is not easily applied. A simple method of checking the theoretical solutions by an etching technique has been developed, and a number of comparisons between theory and practice are given in this section.

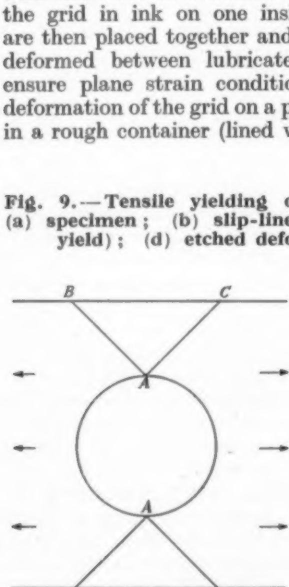
It was shown some years ago[18, 19] that if a suitable annealed mild steel was worked, aged at a moderate temperature and etched in a copper chloride/hydrochloric acid/water etchant, then the plastically worked regions could be distinguished from those which had only been strained elastically. Thus, if a steel specimen of the appropriate shape is deformed slightly and then aged, the pattern obtained on etching can be compared directly with the theoretical slip-line field.

It has been suggested[20] that the best response to this ageing and etching treatment is shown by a steel with a high nitrogen content. For this reason, therefore, a $\frac{7}{8}$ in. thick plate of mild steel made by the basic Bessemer process was used in this work. The experimental technique was as follows. The specimen, which had first

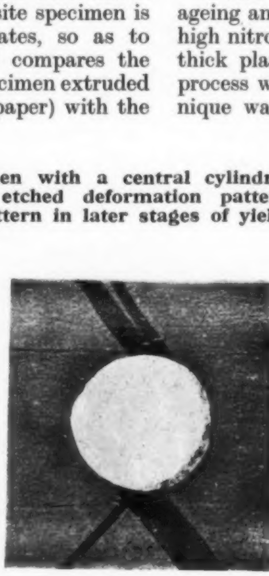
Fig. 9.—Tensile yielding of a specimen with a central cylindrical hole : (a) specimen ; (b) slip-line field ; (c) etched deformation pattern (initial yield) ; (d) etched deformation pattern in later stages of yielding.



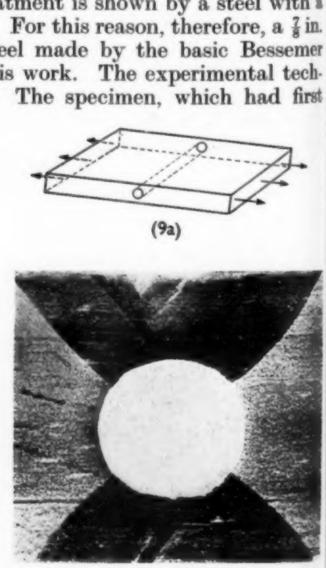
(9a)



(9b)



(9c)



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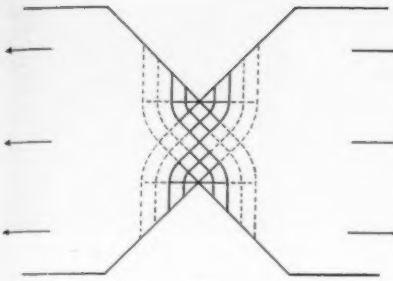
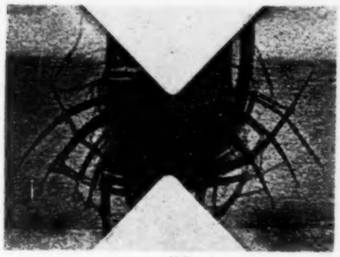


(10b)



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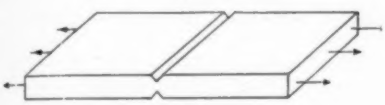


(10a)

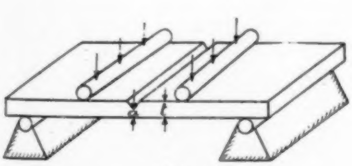
Fig. 10.—Yielding of notched tensile specimen: (a) specimen; (b) slip-line field; (c) etched deformation pattern; (d) etched deformation pattern on end of specimen (conditions not plane strain).

been normalised, was strained approximately 1% in the appropriate manner, and was then aged for 30 minutes at 250° C. A section was cut near the centre line of the specimen and ground on emery papers down to 00 or 000 grade. Etching was carried out by swabbing with a mixture of 45 g. cupric chloride, 180 ml. hydrochloric acid and 100 ml. water. After etching, the specimen was swilled with concentrated hydrochloric acid or methyl alcohol, to prevent staining, and was then washed thoroughly with water, swilled with alcohol and dried.

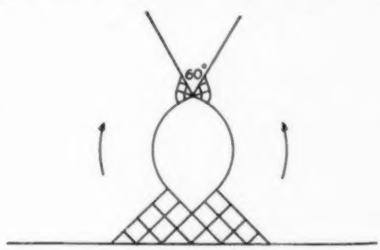
(*a*) *Initial Yielding in Plane Strain.* Plane strain conditions were ensured by choosing the dimensions of the specimens so that the width was at least six times as great as the thickness.

Fig. 8 shows the patterns obtained when a mild steel specimen was indented from both sides, using well lubricated smooth tools (see Fig. 2 and Fig. 21). The slip-line field solution[2,21] depends on the ratio of the specimen thickness t to the tool breadth b, and the corresponding fields are shown alongside the experimental patterns in Fig. 8. For values of $t/b = 1, \frac{1}{2}, \frac{1}{3}$ . . . etc., the metal deforms by shearing on narrow bands, and the pressure needed to cause yielding is the same in every case. When the strip thickness is greater than the tool breadth, however, the slip-line field is more complicated and the pressure needed to cause yielding rises.

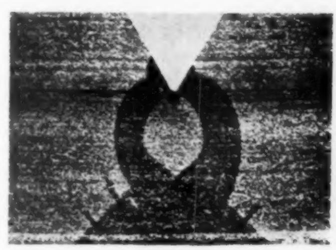
If a bar containing a central circular hole is strained in tension, then the theoretical solution is very simple, and consists of two triangular regions of non-deforming metal bounded by lines of shear. The theoretical solution is shown in Fig. 9*b*, and comparison with Fig. 9*c* shows the excellent correlation with practice that is obtained. If the specimen were strained further, the deformation would not remain confined to the two shear lines, but work-hardening would modify the solution so that the areas ABC in Fig. 9*b* would deform plastically (Fig. 9*d*). The theoretical solution to the problems of the tensile straining of a double notched specimen (90° notch angle) has been given by Hill,[2] and in Fig. 10 (solid lines) this is compared with the experimental pattern found on etching a strained notched bar. The theoretical pattern is that predicted for the initial mode of yielding, and it can be seen that it does not extend as



(11a)

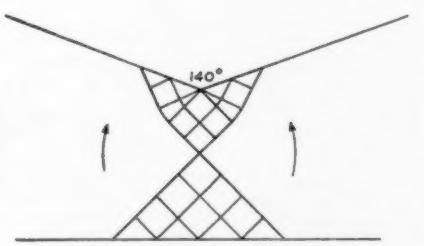


(11b)



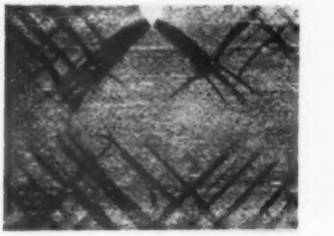
(11c)

Fig. 11.—Bending of a notched bar: (a) method of applying a pure couple to the specimen; (b) slip-line field (60° notch); (c) etched deformation pattern (60° notch); (d) slip-line field (140° notch); (e) etched deformation pattern (140° notch).



(11d)

(11e)



(12a)

(12b)

Fig. 12.—Bending of a shallowly notched flat bar: (a) etched deformation pattern when $t/a = 1\cdot 1$; (b) etched deformation pattern when $t/a = 1\cdot 24$.

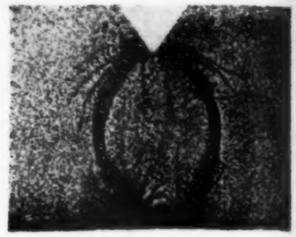


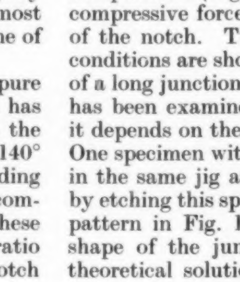
Fig. 13.—Etched deformation pattern of a Charpy V-notch impact specimen.

far as the observed pattern. This theoretical solution is not unique, as the field could be extended to the broken lines in Fig. 10 without violating any of the laws of plasticity, and it is clear from the experimental pattern that, even if the field is confined to the initial region at the instant of yielding, the work-hardening causes expansion of the field almost immediately. The pattern shown in Fig. 10*c* was obtained when a section taken from the centre of the bar was polished and etched; this pattern represents therefore the plane strain solution. The conditions near the end face of the specimen are not plane strain, and it is interesting to see (Fig. 10*d*) that the pattern of deformation on the end face is slightly different from that in the centre of the bar, the most marked difference being the presence of a central zone of non-deformed metal.

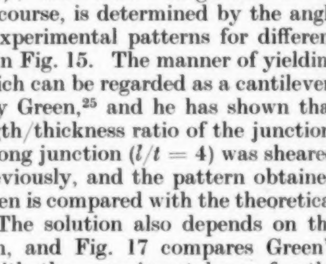
Green[22] has recently analysed the bending by a pure couple of a flat bar containing a deep notch, and has shown that the mode of deformation depends on the angle of the notch. Specimens with a 60° and a 140° notch, on one side only, were bent in a four point bending jig, and the resulting patterns from these tests are compared with the theoretical predictions in Fig. 11. These patterns were obtained for deep notches, i.e., the ratio of the bar thickness to the thickness below the notch t/a was $2\cdot 0$. As the notch depth is decreased, the pattern of deformation and the theoretical solution remain the same until, at a critical depth, the deformation spreads to the surface. At present, the theory can only suggest that the critical ratio of t/a for a 60° notch, is greater than $1\cdot 13$. Two experiments with notches of different depths were carried out, and the results in Fig. 12 indicate that the critical ratio is at least $1\cdot 25$*. This type of solution has an obvious application to the Izod and Charpy notch-bend tests, and an analysis of these tests, using this theory, would probably further our understanding of their meaning in relation to the problem of brittle fracture.[23] The manner of deformation will be slightly different from that in the case analysed by Green, as the bending is not due to a pure couple, nor is the deformation plane strain. A Charpy V-notch specimen was strained slightly (2 ft./lb. impact) so as to compare the mode of deformation in this case with that given earlier. A comparison of Fig. 13 with Fig. 11 shows that the experimental patterns are similar, and it should, therefore, be possible to apply Green's theory to these tests.

Another problem that has recently been investigated by Green is the shearing of junctions.[24, 25] Fig. 14*a* shows the type of junction considered, and the experimental method of shearing the specimens, without any rotation of the ends, is shown in Fig. 14*b*. The region of deformation of a short junction is shown in Fig. 14*c* and can be compared with the slip-line field solution given in Fig. 14*d*. The manner of yielding is affected when a force normal to the junction is imposed in addition to the shearing force, e.g., if the junction is compressed as well as sheared. Combined stresses of this nature were obtained in practice by compressing specimens containing notches cut at an angle to the direction of compression (Fig. 15*a*); the relative magnitude of the compressive force, of course, is determined by the angle of the notch. Two experimental patterns for different conditions are shown in Fig. 15. The manner of yielding of a long junction (which can be regarded as a cantilever) has been examined by Green,[25] and he has shown that it depends on the length/thickness ratio of the junction. One specimen with a long junction ($l/t = 4$) was sheared in the same jig as previously, and the pattern obtained by etching this specimen is compared with the theoretical pattern in Fig. 16. The solution also depends on the shape of the junction, and Fig. 17 compares Green's theoretical solution with the experimental one for the

* Since these experiments, Green (to be published) has calculated the critical ratio to be about $1\cdot 4$ for a 60° notch.



(14a)



(14c)

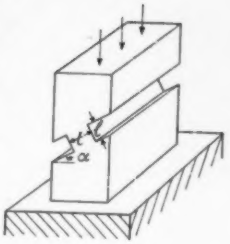
(14b)

(14d)

Fig. 14.—The shearing of a junction: (a) specimen; (b) method of shearing (the ends are firmly clamped to prevent rotation); (c) etched deformation pattern ($l/t = 1$); (d) slip-line field.

shearing of a junction with curved sides. The radius of curvature of the sides of the junction was 2·0 in., and the thickness at the minimum section was 0·35 in. Again the agreement between theory and practice is excellent.

It is apparent, from a comparison of the experimental patterns and the slip-line fields presented in this section, that the edges of discrete markings in the experimental patterns are roughly parallel to the directions of maximum shear stress (the slip-lines) in the deforming specimen. This suggests that this experimental method could prove of great use to the theoretician, as an examination of the experimental pattern should suggest the correct slip-line field at once. This would save him the time involved in guessing the form of the field and then checking it theoretically.



(15a)

(15b)

(15c)

Fig. 15.—Shearing of junctions with a superimposed stress: (a) specimen; (b) etched deformation pattern for $\alpha = 15°$ and $l/t = 1$ (normal compressive stress = 3·7 × shear stress); (c) etched deformation pattern for $\alpha = 4°$ and $l/t = 0·55$ (normal compressive stress = 14 × shear stress).

(*b*) *The Spreading of the Deformation Zone.* According to the theory, which assumes a non-work-hardening plastic-rigid body, the deformation would still be confined to the predicted slip-line field, even after large plastic deformations, provided there was no pronounced change in shape of the specimen. In practice, however, most metals work-harden and the deformation zones alter in size and shape as the strain increases.

The spreading of the deformation zone is illustrated in Fig. 18, which shows different stages in the yielding of a long junction in plane strain; Fig. 16*b* should be considered as forming part of this series, falling between Fig. 18*a* and Fig. 18*b*. Initially (Fig. 18*a*) the yielding takes the form of a number of discrete bands parallel to the lines of maximum shear stress (the slip-lines), and, as shearing is continued, these increase in size and merge with one another until the whole of the area covered by the slip-line field has yielded uniformly; further shearing then leads to an increase in the size of the deformation area, though it still retains its general shape (Fig. 18*c*). In this particular case, as the plastic boundaries move out, the load needed to cause further yielding rises, and an alternative mode of yielding can come into operation. Theory suggests that this alternative mode takes the form of a circular slip-line running across the root of the junction (Fig. 18*d*), and in practice we can see that this solution is approached, even though it is not followed exactly. The filling in of the deformation area, and the spreading of the plastic boundaries as the strain is increased, appear to be quite general and have been observed in most of the experiments described here.

It is probable that this particular form of yielding is confined to metals, like the mild steel used here, where the initial part of the stress-strain curve is flat, i.e., there is no work-hardening. Yielding in a work-hardening metal with a rounded stress-strain curve will probably occur in a much more diffuse manner.

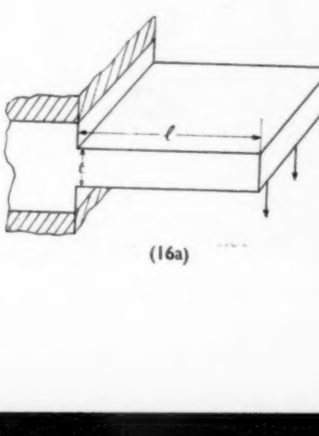
(*c*) *Yielding in Plane Stress.* There are comparatively few solutions in plane stress, but the shearing of a thin junction is shown here as a typical example. The specimens were sheared in the same jig as that used for the plane strain experiment, and pieces cut from the plane strain specimens formed the specimens for the plane stress experiments: they were machined down to a thickness of $t/6$ at the junctions, and the final shape of the specimens is indicated in Fig. 19*a*. Figs. 19*b* and 19*d* show the deformation patterns obtained, and it can be seen that they are quite similar to those in plane strain (Figs. 14 and 16). The theoretical characteristic fields are shown in Figs. 19*c* and 19*e*. The short junction pattern is very similar to that in plane strain, and the only difference with the long junction is that the circular arc in the centre of the deforming region has nearly disappeared. Theory predicts that the form of solution should change at an l/t ratio of 5·65, and that the circular characteristic should vanish at this point. The l/t ratio for this specimen is 4, so that it gives rough agreement with the theory. The limiting ratio in plane strain is much higher ($l/t = 27·5$) so that the circular slip-line would be expected to be more pronounced in this case.

Comparison of Loads

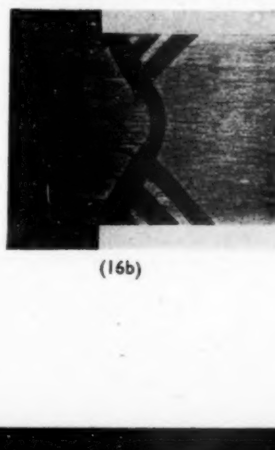
1. *Continuous Forming Processes.*

The forces needed to deform a metal in a process such as rolling or wire drawing can often be predicted by

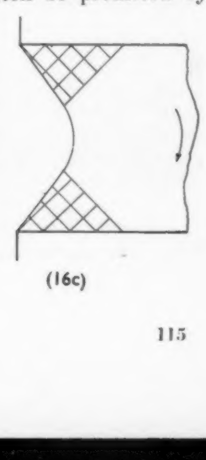
Fig. 16.—Yielding of a cantilever ($l/t = 4$): (a) shape of specimen; (b) etched deformation pattern; (c) slip-line field.



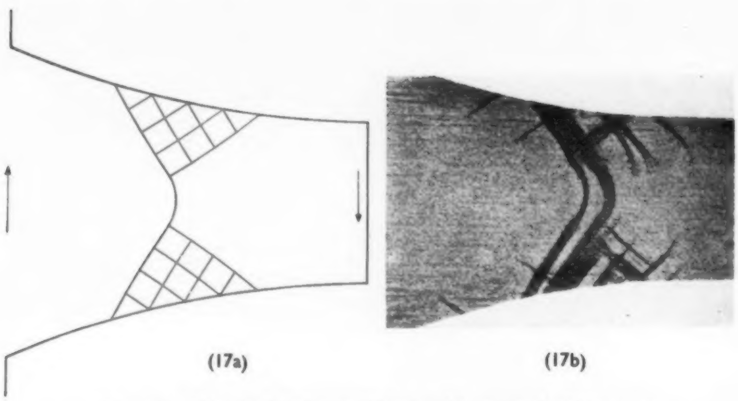
(16a)



(16b)



(16c)



(17a) (17b)

Fig. 17.—Shearing of a junction with curved sides: (a) slip-line field; (b) deformation pattern.

theory. These predictions, if accurate, can be most useful in the field of equipment design and in obtaining maximum efficiency from the equipment, and a good deal of work on these lines has been carried out.

Although there is no slip-line field solution for the rolling process, a number of approximate theories have been developed[26, 27, 28] which are generally regarded as fairly satisfactory. The advent of suitably designed load and torque-meters[29, 30] has enabled a large number of measurements of the roll loads and torques to be made in recent years, for both hot and cold rolling. Generally, the theoretical predictions are in good agreement with these measured values, provided that a suitable value of the coefficient of friction is chosen (the actual value depends on the metal being deformed and on the conditions of rolling, but it normally falls in the range 0·05–0·08). Calculated and measured values of the roll loads in cold rolling, taken from a number of sources in the literature[31, 32, 33] are compared in Fig. 20. These results are for different metals and different rolling conditions, and it can be seen that the agreement between the predicted and measured loads is very good; equally good agreement is obtained for values of the torque, but these figures are not reproduced here. The agreement between theory and practice is not quite so good in hot rolling,[34] and this is mainly due to the lack of accurate data on the coefficients of friction and the yield strengths encountered during hot rolling. Despite this, the theory can still give results which are within 50% of the correct figures.

Wistreich has recently compared various theories of wire drawing with experimental results obtained by drawing copper wire through split dies.[35] Of the various theories advanced, that due to Siebel[4] gives very good agreement with experiment. Over most of the range of loads encountered, theoretical predictions of the drawing force were within about 10% of the measured value, and even at the extreme ends of the range the values agreed to within 30%.

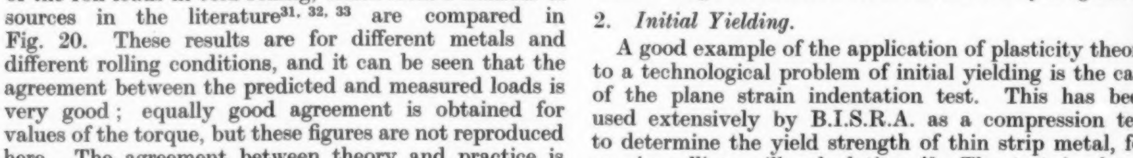
Purchase and Tupper[14] have compared the pressures needed to extrude lead under conditions of plane strain with those predicted by theory, and have obtained agreement to within about 5% for reductions ranging from 34% to 90%. Experiments carried out at Sheffield University suggest that it might be possible to use this plane strain extrusion theory to predict the working pressures in rod extrusion,[36] but there are not yet sufficient results available to give any definite idea of the accuracy to be expected from this application.

Nye[37] has also used lead in experiments on the plane strain compression of a block between rough plates. He obtained good quantitative agreement between the predicted and measured yield stresses in these tests.

Tabor[38] has applied plasticity theory in an empirical manner to the Brinell and Vickers hardness tests, and has shown that it is possible to determine the stress strain curve of a metal to an accuracy of better than 10% from a number of such tests. This work is an excellent example of the application of the simple principles of plasticity to obtain further valuable information from a simple test. Similar results were obtained from plane strain wedge indentation tests carried out by Dugdale.[39]

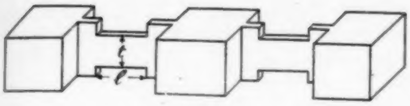
2. *Initial Yielding.*

A good example of the application of plasticity theory to a technological problem of initial yielding is the case of the plane strain indentation test. This has been used extensively by B.I.S.R.A. as a compression test to determine the yield strength of thin strip metal, for use in rolling mill calculations.[40] The test is shown schematically in Fig. 21. A well lubricated strip of the metal is compressed between the carbide dies and the depth of indentation measured with a hand micrometer. By repeating this process at different loads, a "stress-strain" curve can be obtained which, when extrapolated to zero strain, will give the stress at which yielding first



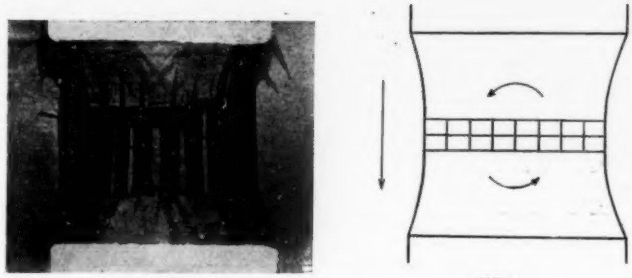
(18a) (18b) (18c) (18d)

Fig. 18.—Spreading of the deformation zone during the shearing of a cantilever: (a) bent 0·5°; (b) bent 1·5°; (c) bent 2·5°; (d) alternative mode of deformation.

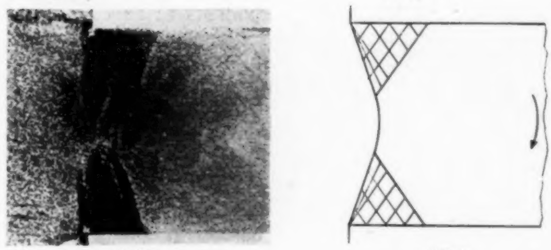


(19a)

Fig. 19.—Shearing of thin junctions (plane stress): (a) specimen; (b) etched deformation pattern (l/t ∽ 1); (c) characteristic field (l/t ∽ 1); (d) etched deformation pattern (l/t ∽ 4); (e) characteristic field (l/t ∽ 4).



(19b) (19c)



(19d) (19e)

occurred. This flow stress depends on the ratio of the strip thickness to the tool breadth t/b and it is only when $t/b < 1$ that it is approximately equal to the yield strength of the metal. Watts and Ford[41] have carried out a very careful investigation of the variation of flow stress with tool geometry, and their results are reproduced in Fig. 21, together with the theoretical curve deduced by Hill.[2] The agreement is very close, and it seems that the test could be used with some confidence to determine yield stresses, especially in the range $t/b < 1$.

In many cases, the "stress-strain" curve determined in this way agrees closely with that determined by tensile tests, and it is frequently used for this purpose. Satisfactory agreement between the indentation and tensile stress-strain curves is obtained for simple materials such as copper, mild steel and aluminium, but the agreement is poorer for materials which have a more complex metallurgical structure, such as high carbon steels, or which undergo a phase transformation on cold working, such as stainless steel. However, even with these materials, the test gives good agreement with theory for the initial yielding. This is shown in Fig. 21, where experimental results obtained by the author for 18/8 stainless steel are plotted. The agreement with theory is almost as good as for the more ideal metal, cold-worked copper.

Hill and Siebel[42] have compared the theoretical and experimental elastic limits and collapse loads for solid steel bars that were simultaneously bent and twisted. The results showed that plastic-rigid yield-point loads could be safely used in design calculations. The measured total distortion was less than twice that at the elastic limit, so long as the actual loads did not approach within about 5% of the theoretical yield point values; i.e., there is no danger of collapse if the actual loads do not come within 5% of the theoretical collapse loads. Similarly, Crossland and Hill[43] have shown that the load at which an autofrettaged cylinder becomes completely plastic can be predicted by theory to within about 3%. They also determined the collapse loads of thick steel cylinders twisted under various internal pressures, and compared these with the theoretically predicted loads. The agreement was excellent (within 2%) and was virtually within the experimental error of the tests.

Table I shows the results of measurements on the bending of bars notched on one side (Fig. 11*a*). The bending moment at yield was calculated from the theory,

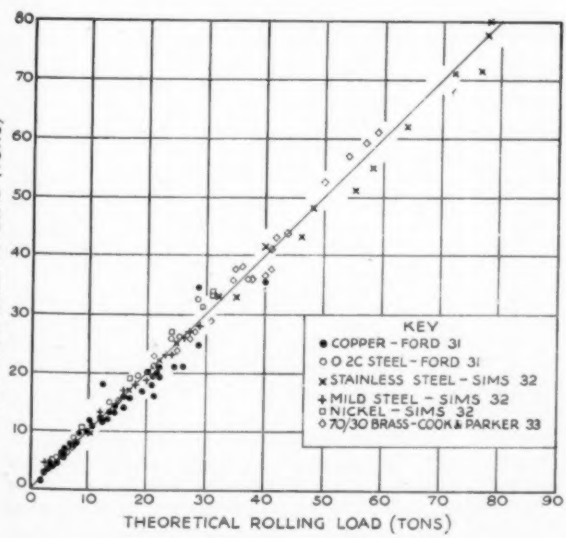


Fig. 20.—Comparison of rolling loads predicted by theory with those measured in practice.

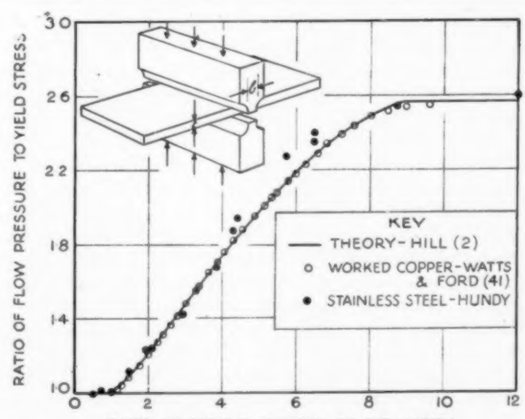


Fig. 21.—The variation of indentation pressure with geometry for the deformation of metal strip between narrow dies.

TABLE I.—COMPARISON OF THE THEORETICAL AND EXPERIMENTAL BENDING MOMENTS FOR THE BENDING OF A NOTCHED BAR IN PLANE STRAIN.

Metal	Notch Angle	Measured Bending Moment at Yield (ton.in.)	Theoretical Bending Moment at Yield (ton.in.)
Cold-worked Copper	140° 60°	0·605 0·715	0·597 0·700
Annealed Copper ..	140° 60°	0·045 0·049	0·044 0·048
Annealed .. .. Stainless Steel	140° 60°	0·681 0·770	0·750 0·860

and it can be seen that the agreement with practice is moderately good. Better agreement in this case was obtained with copper specimens than with stainless steel ones; this might be due to the fact that stainless steel is not an ideal material, but is more probably due to anisotropy.

Conclusions

The experimental work which is presented here shows, in most cases, that the theory of plasticity is often capable of predicting correctly the mode of deformation, and the applied loads during the deformation, of metal bodies. It seems that the plastic-rigid theory can predict accurately the onset of yielding, even in a metal that is far from the ideal plastic-rigid material (such as stainless steel), and can be used with every confidence in such cases. The correlation between theory and practice, in the case of the continuous forming processes involving large plastic deformations, is probably not so good, especially in the case of non-ideal metals. However, the results given here show, even in such cases, that the theory can probably predict the loads and forces to an accuracy of about $\pm 10\%$—which is accurate enough for most purposes. There is no doubt, on the whole, that application of the theory of plasticity should give much better process control than the rather empirical methods which are used to a great extent to-day, and the theory will probably be used to a much greater extent in a few years time than it is at present.

Acknowledgments

The author would like to thank Mr. A. P. Green for his useful comments on the theoretical aspects of this paper; Messrs. D. L. Phillips and W. C. F. Hessenberg for their suggestions concerning the experimental etching technique; Messrs. T. D. Boxall, D. Burton and B. Coldwell for their careful experimental work; and Mr. W. F. Gilbertson of Messrs. Richard Thomas and Baldwins, Limited for supplying the plate of basic Bessemer mild steel.

Acknowledgment is also made to Mr. A. P. Green and Messrs. Taylor & Francis, Ltd., for permission to reproduce Fig. 14*d*, which appeared as Fig. 7*bc* in *The Philosophical Magazine*, 1951, vol. 42, page 305; and to Mr. A. P. Green and The Clarendon Press for permission to reproduce Fig. 19*c*, which appeared as Fig. 11*ce* in *The Quarterly Journal of Mechanics and Applied Mathematics*, 1953, vol. 6, page 223.

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Expansion at Marconi Instruments

MARCONI INSTRUMENTS, LTD., St. Albans, have greatly increased the productive capacity of their Longacres works by the opening of a new factory wing. Several sections of the business have been re-organised, permitting a smooth flow of production and distribution at the new level, and a new design centre provides improved facilities for the Company's engineers. These measures will, it is hoped, enable the company to cater adequately for expanding business both at home and abroad. A notable feature of the new layout of the works is the strategic placing of the various stores sections, permitting smooth issue of components and raw materials to adjacent assembly departments and the machining sections. In the seven years since the Works was centralised at Longacres, St. Albans, it has more than trebled in size, and with the new layout may well be considered a model for efficient production on one floor.

Believed to be one of the largest organisations of its kind in the world, the Company designs and produces the widest range of communications test equipment. In the industrial field, also, the Company has had considerable success with a range of moisture meters and pH equipment, whilst Marconi Instruments X-ray and electro-medical equipment is widely used in hospitals both in this country and abroad.

The Company, a subsidiary of Marconi's Wireless Telegraph Co., Ltd., and a member of the 'English Electric' group of companies played its full part in the 1939-45 war, producing over 50,000 instruments, chiefly for the maintenance of communications, a further 9,000 being made on sub-contract by other firms. Some capacity was also devoted to industrial measuring equipment for use by companies engaged on Government work, and certain electro-medical apparatus was produced for hospital units in the field.

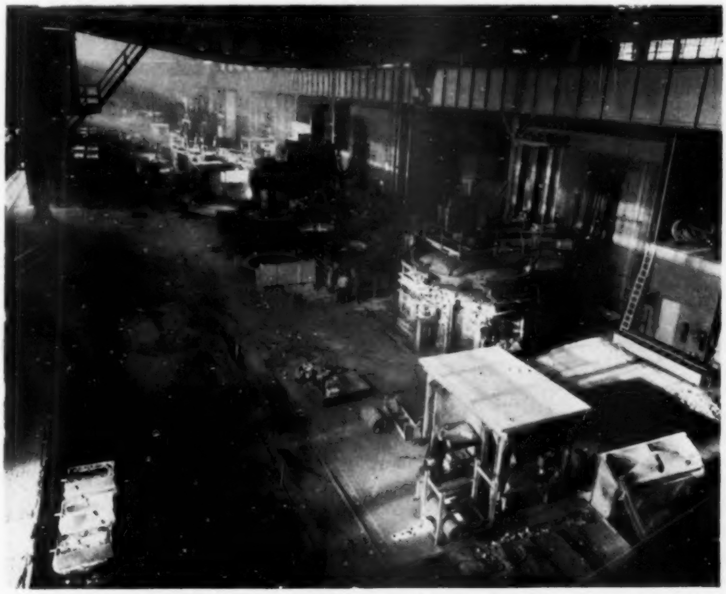
BRITISH INSULATED CALLENDERS' CONSTRUCTION CO. LTD. recently moved into new premises at 30, Leicester Square, London, W.C.2, where their telephone number is TRAfalgar 7777. It should be noted that the Central Administration Offices of the parent Company, British Insulated Callenders' Cables, Ltd., remain at 21, Bloomsbury Street, London, W.C.1.

The Electric Arc Steel Melting Furnace

Some Aspects of Its Use for Lower Grade Steels

Considerable progress has been made in the United States in the application of the electric arc furnace to the production of plain carbon steels. Following a reference to some of the factors governing the choice between the arc furnace and the open hearth furnace, an account is presented of an informal talk given by Mr. J. C. Howard, a Director of Electric Furnace Co., Ltd., on his recent tour of arc melting plants in the United States.

ALTHOUGH steel has been made in electric arc furnaces for half a century, the process has been mainly confined to the production of high quality alloy steels, for which it is particularly suitable. The last few years, however, have seen improvements in furnace design and operating technique which have materially lowered electric steelmaking costs to the point where use of this process in the production of plain carbon steels appears to be almost competitive with the open hearth process, and in the United States a number of furnaces are operating on this class of steel.



General view of the furnace bay of an arc furnace melting shop housing four 18-ft. diameter 80/90-ton furnaces.

The power requirements of large electric furnaces are considerable, and any upward trend in their use would create important new demands for electric power, and for the coal necessary for its production. In consequence, in 1951 a group of 14 electric utility companies in the United States combined with Bituminous Coal Research Incorporated to sponsor a study at Battelle Memorial Institute that would critically appraise the present and potential competitive aspects of the arc furnace and open hearth process for the production of plain carbon steels with a maximum carbon content of 0·25%.

Economic Aspects

The results of this investigation have now been revealed in a report issued by Battelle, and in a recent article, Robiette* has discussed the findings in the light of conditions prevailing in Britain. As the arc furnace is essentially a scrap melting and refining unit, comparison is made with cold-metal open hearth practice, and on the basis of a 250,000 ton/annum output the capital charges are about 60% of those for the open hearth plant. This favourable feature of the electric furnace is supported by the very considerable reduction in charging time made possible by the top-charging technique, even where light scrap necessitates back-charging, or alternate charging and melting. Furthermore the faster melting rate possible means that a 60–70 ton arc furnace is the equivalent, from the point of view of output, of a 160–180 ton fixed open hearth furnace. Minor factors also tending to a reduction in capacity for a given output are the increased availability, due to easier repairs, and the slightly increased metal yield, due to the absence of gaseous oxidation.

On running costs, however, the cost of producer gas per ingot ton is less than the cost of the electrical energy needed in the arc furnace, and to the latter must be added the cost of the electrodes consumed, which amounts to almost half the cost of the power. On the other hand, refractory costs are lower for the electric furnace by some 40% and the labour costs by about 20%.

The sum total of the costs of all the factors concerned is very little different for the two processes, and slight changes in the costs of individual items could sway the advantage one way or the other. Apart from costs, however, the arc furnace has certain points in its favour. For instance, it is much more flexible: it is quite easy to make heats half the size of the normal ones, and, as it is a tilting furnace, to pour more than one composition per heat. At any time, two-slag operation can be employed to make low-sulphur high quality steels, and the fact that temperature is more readily controlled is a further aid to quality in the finished product. Furthermore, the arc furnace can operate single shift working when demand is low, whereas the open hearth furnace must be worked continuously: the lower capital costs

* *Iron and Coal Trades Review*, Nov. 27th, 1953.

also make the arc furnace better able to withstand periods of low demand.

American Practice

Sufficient has been said to show that, in certain circumstances, the arc furnace merits consideration as a producer of the lower grades of steel. That British steelmakers are not disinterested in the development was shown by the attendances at the informal talks given in Glasgow and Sheffield by Mr. J. C. Howard of the Electric Furnace Co., Ltd., who described some of the features of American practice which he had noted on a recent visit to the United States. Some of the main points of Mr. Howard's talk are given below.

The main purpose of the visit to the U.S.A. was to study the use of large arc furnaces in that country for the production of lower grades of steel. An arc furnace can make the cleanest steel possible, low in sulphur and phosphorous, and it is not suggested that British steelmakers should relax the standards of quality of their high grade steels, but Americans consider that it is bad engineering to make anything better, and therefore more expensive, than it need be. This has led to a wider application of the arc furnace, in that it is being increasingly used to replace the basic open hearth furnace melting cold charges. Rimming steels and semi-killed steels are now frequently made by a single slag process in arc furnaces. One example of this is an installation of two 22 ft. diameter furnaces, each with a 25,000-kVA transformer, making plain carbon steels for the production of wire and wire nails and working to two carbon specifications only. The scrap is melted rapidly and superheated, a few finishing additions made and the heat poured. No chemical analysis is made and the quality of the steel is judged by a quick physical test. Each transformer can have its rating increased to 35,000 kVA. by putting on a special forced water cooled heat exchanger, but it is very doubtful if such a power can or will be used.

More care is taken with steels for more important duties. For example, steel for transformer irons is in one plant made in 18 ft. diameter furnaces. The melt is decarburised with oxygen, and when both carbon and sulphur are low enough, the heat is " blocked " with a little silicon. The final addition of silicon is made in the ladle. If analysis shows that tramp elements are too high in the first bath sample, the heat is diverted to some other use.

It would obviously help to eliminate this trouble with tramp elements, if a far higher proportion of pig iron (preferably liquid) to scrap were used. This has been tried in the U.S.A., but the great difficulty is the large slag bulk involved.

Bessemer Converter—Arc Furnace Duplexing

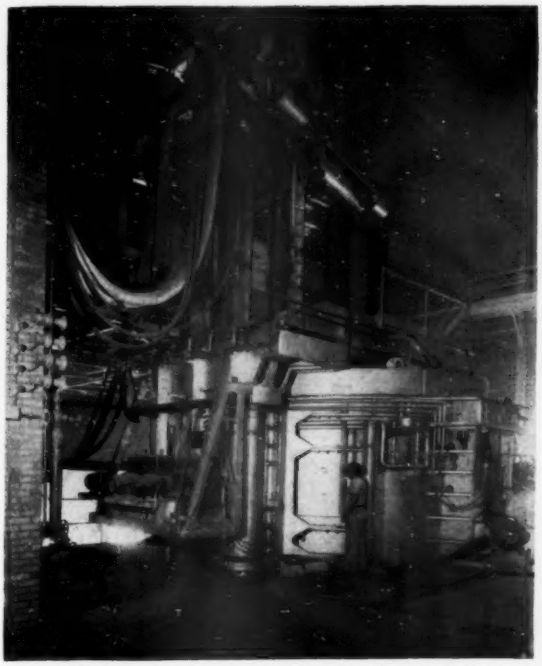
A new plant is now being built, in which two 24-ft. diameter furnaces with 25,000-kVA. transformers may be used for duplexing, with three 35-ton side blown converters. This duplexing with Bessemer converters has been well proved in eastern France. The addition of a large arc furnace to a Bessemer shop, where it will take odd heats from the converters, makes a good set-up. The converse is not so satisfactory. Doing the preliminary oxidation of the silicon and manganese in converters does mean that the subsequent slag in the arc furnace is much less bulky. A very hopeful proposal on the same lines, is to blow liquid iron in a modified ladle with an oxygen lance, following the technique established for arc furnace practice, but just to oxidise the silicon and manganese. The excess slag could then be decanted off and the hot, high carbon iron transferred to an arc furnace, where the carbon can be easily removed. Some modifications to the furnace to deal with the extra gas given off may be necessary.

As an example of the American approach to alloy steel making in an arc furnace, an 80-ton heat of 18/8 stainless steel in an 18 ft. diameter furnace is instructive.

American furnace shops are well-equipped with mechanical handling tools as represented by this fork lift run-about used for bringing up raw material.

Using a B.R.I. gun for repairing the side walls of an arc furnace by spraying with a mixture of a refractory cement and water.

Typical control panel for a large arc furnace showing the substantial protection afforded against the possibility of flying material during charging.



View of 80-ton top-charged furnace showing the roof raising and slewing mechanism, the water-cooled flexible furnace leads, and the pneumatic cylinders for the automatic control of the electrode holders.

The charge of scrap and high carbon ferro-chrome is selected to melt out at about 14% chromium and 0·6–0·8% carbon. The charge is superheated to 1,650° C. and then blown with oxygen until the carbon is down as required, the chromium about 7% and the temperature about 1,850° C. Blowing is then stopped and the chromic oxide reduced back out of the slag with chromium silicide. Lime is added to keep the lime/silica ratio about 1 : 1. Slagging off follows by pouring the whole charge into a ladle, decanting the slag and then pouring back the steel into the furnace, having swung aside the roof. Final alloy additions are made in the furnace.

For plain carbon steels, carbon removal is still commonly effected by boiling down with ore or, more frequently, with scale charged through the roof of the furnace with a magnet. A carbon removal rate with scale of half a point per minute is achieved, which is about half that obtained with oxygen lancing.

American steelmakers swing the roof off large furnaces more frequently than do their British counterparts, not only for charging lime, ore, ferro-alloys, etc., but even for stirring the bath, when a slab of steel with a knob of slag on the end of it is moved through the bath by the crane to give complete mixing. Slagging off, in the British sense, is practised less frequently. If enough slag will not run off on its own, the technique described earlier is often employed.

Fumes are a problem, and are sometimes dealt with in one of two ways. Smaller furnaces up to 15-ft. diameter, have a sheet steel canopy following the roof brickwork and about 6 in. from it, and a hood over the door. Fumes are sucked from under this canopy by a large fan. Larger furnaces sometimes have a separate hole in the roof for which the fumes are exhausted via ducting.

Refractories

Refractory repairs are frequently effected by machine. One interesting tool is a gun which injects a stream of water, air and a special magnesite powder, so that the operator can build up worn sections of the hot wall. Patches as strong as the original can be obtained. Water bonded magnesite hearths are often used, and claims for a life of years made, but it is not certain that they are, in fact, superior to the graded dolomite hearths used over here. Side walls are usually magnesite, but never more than 13 in. thick, and it may be doubted if our 18 in. walls are really necessary.

Taper nipples for the electrodes are standard, and some users prefer a nipple rather smaller than standard. The joints are frequently dowelled after tightening.

One 20-ft. diameter furnace with a 20,000 kVA. transformer was inspected, where an ASEA electric stirrer has been fitted. It is found that sulphurs of 0·005% to 0·007% are common, where similar techniques in similar furnaces without electric stirrers give sulphurs of about 0·02%. This results in much less scrap from the rolling mills. Exceptionally low carbons are also far more easily obtainable. The uniformity of temperature and the homogenity of the bath are also remarkable, but the usefulness of the stirrer during slagging-off is more questionable.

Six-Electrode Furnaces

As furnaces increase in size it is possible that the normal three-electrode furnace may give place to a six-electrode furnace with two separate transformers, an arrangement which has advantages from many points of view. At the Timken plant in Canton, Ohio, there are in operation a 100-ton six-electrode furnace, with two transformers of 7,500-kVA. rating, and a 100-ton three-electrode furnace of 20,000 kVA. rating. Experience has shown that the six-electrode furnace has a

higher melting rate than the three-electrode furnace, in spite of the greater power available for the latter.

The fact that it might be desirable to instal arc furnaces for the production of common steels in existing open hearth shops gives rise to certain difficulties of design, due to the fact that there may be insufficient height from the stage to the crane gantry for a conventional furnace, complete with electrodes, masts, etc., to be tilted without the masts fouling the gantry. One solution to this problem is to attach the electrodes to the shop structure so that they do not tilt with the furnace. With a suitable design it should be possible to tilt the slight amount necessary for slagging-off without withdrawing the electrodes: they would of course, be withdrawn completely during tapping.

The arc furnace is not particularly suitable for dealing with liquid pig iron, and it was suggested during the discussion following Mr. Howard's talk in Sheffield that the ideal combination is a top-blown vertical oxygen jet converter and an arc furnace. The converter can accommodate some scrap, but not all that arises in an integrated plant, the remainder being dealt with by the arc furnace, which can also take liquid converter metal for further refinement.

Presenting a Technical Paper

By C. H. Willcocks

To those faced with the task of preparing a technical lecture for the first time, many problems of a general nature present themselves. In this article, a number of suggestions are made which will help both in compiling the subject matter and in getting it across to the audience.

MOST people who rise to responsible positions in the technological field will at some time be faced with the task of writing and presenting a technical paper. At first the amount of work involved appears formidable, but if it is tackled methodically, the writer can derive considerable pleasure from it. Also, he will advance his own education, because some new facts will almost certainly come to light during the process of compilation. A well-knit paper which provokes a spirited discussion will confer professional prestige upon its author. Above all, there is the deep satisfaction of a job well done. In this article, a method of approach is suggested, by means of which the work can be broken down into easy stages, each of these being taken separately as time and opportunity permit.

The Subject

In some cases, the choice of subject is left to the author. If he has been engaged on independent investigations, and has some new knowledge to communicate, then the form and content of the paper will decide themselves. Unfortunately, it is more usual to find the author wondering, " What on earth shall I talk about ? " In these circumstances he will be well advised to choose some aspect of his daily work with which he is familiar. This will enable him to give as good as he gets in the thrust and parry of argument. At the same time, it ensures that sources of material and means for research are ready to hand. If the author is asked to deal with a set topic, it is probably because it is well known that he has above-average experience in that particular field.

The inexperienced author tends to set himself an impossibly high standard, both in literary style and in the amount of new knowledge to be embodied in the paper. Some hints on style will be given later. As regards new matter, it may be said at once that most technical papers contain very little that is new. Indeed, many excellent papers are no more than summaries of the present state of knowledge in a special field, leavened by a few controversial opinions.

In most industries, it is not difficult to find a subject on which no paper has been read for five or ten years, during which time a number of developments have occurred. None of these may be of great magnitude in itself, but together they provide sufficient substance for a paper. If such material seems commonplace to the author, he should remember that the majority of his audience will not be quite so familiar with it, and they will be pleased to have a bird's eye view of the field, if only to assure themselves that it contains nothing new that they ought to know.

If, as is usually the case, the paper is to be presented with the object of stimulating a discussion, the subject selected should not be so highly specialised that only one or two members of the audience are capable of making informed comments upon it. On the other hand, there is no need to water down the subject until it becomes a topical commentary on the state of trade. Perhaps the best compromise is a subject about which the author knows as much as anyone, and with which all are concerned in some degree.

If the society includes representatives of accessory manufacturers or rival material suppliers, the success of the meeting is assured by including in the paper some provocative opinions which will bring these " ambassadors of commerce " to their feet. The controversy will stimulate their customers to air their opinions and grievances and the author may be rewarded with the sight of half-a-dozen would-be speakers straining to catch the chairman's eye.

Planning

The title of the paper should give a fair indication of the scope of the contents, but it should be concise. A long and pretentious title, loaded with unnecessary qualifications, gives a bad impression, besides being a nuisance to the other people who will need to refer to it in correspondence and advance publicity.

Before plunging into technical detail, the author should give a brief introduction. The object of this is not to summarise the contents of the paper, but to guide the thoughts of the audience in the general direction to be followed. This part of the paper should be kept short, resisting the temptation to advance arguments which

will be fully developed in the text. In, fact it is better to leave the writing of the introduction to the last. By that time the appropriate form of words will suggest itself more readily.

An acceptable length for a technical paper is five thousand words or twenty quarto pages of double-spaced typescript. This wordage is soon swallowed, particularly by factual detail: consequently, planning is necessary to avoid waste of time in collecting material which would have to be discarded subsequently owing to shortage of space. For many people, the best procedure is simply to sit and think, and not to write anything at all until the broad outline of a possible discourse on the selected subject takes shape in the mind. Then it is possible to write down a series of section headings, but there may be doubt about the finished length of some of these sections.

Research and Compilation

Much of the subject matter will come from the author's memory of his professional experiences, and from his own opinions, which will come to mind readily. A first-class paper should bear comparison with previously published work in the same field, so one of the first steps is to list the relevant literature of merit, and to make sure that one has a general idea of its content. As the result of the war and its after-effects on publishing, many technical subjects are sparsely covered in print, and the author may find that there are only one or two books or papers with which he need concern himself. There is no need to study these in great detail; the object is to avoid duplication, and to find a departure point. In most cases, the author will find that in bringing the previous paper thoroughly up to date he has filled his allotted time, and done all that is expected of him.

Other valuable sources of information are the records of the author's own organisation, the research and development departments of commercial firms, industrial research associations, and the technical press. Digging out information takes time, particularly when one has to apply to other people, who may not be able to attend to the inquiry immediately. Any requests for information or illustrations should, therefore, be sent off as early as possible.

When the bulk of the essential information is in hand, one or more of the principal sections of the paper may be written, consisting probably of a block of facts with arguments based upon them. The danger here lies in being side-tracked by unnecessary detail. Items of interest that are not essential to the theme should be excluded at this stage. They can be added later as decoration, if there is room for them. A count of the wordage of the completed sections will show how much space is left for the remainder. It is then possible to see whether all the proposed material can be used, and how much further the researches need to go. When this decision has been made, the back of the job has been broken. The remaining sections are written to length, and when they are done, the paper is in being. If possible, let a day or two elapse before attempting to revise and polish it.

Style

Technical papers should be written in functional English, which is poles apart from the language of imaginative English literature. There is no place for such literary devices as over-statement or under-statement in functional English, but it is not merely a matter of leaving out all figures of speech. The aims of a functional style are not only simplicity and clarity; above all the author must maintain receptivity in the minds of the audience, and this demands some knowledge of psychological conditions. The main point to remember is that the mind of the hearer requires considerable time in which to perform the successive acts of associating, understanding and memorising. Concise sentences may look well on paper, but they may be impossible to understand when read aloud, because the minds of the audience may be unable to cope with so many significant statements following one another in quick succession. The expositor must vary his pace according to the familiarity of the material, adding introductory expressions, and tactfully introducing alternative explanations of unusual technical terms. New and unexpected statements should be signalled well in advance, otherwise their import may be entirely missed by the audience. If an unexpected statement is not adequately introduced, the audience may not only miss it, but may actually think they heard the contrary, if the contrary is what they were expecting. Consider not only what the audience know, but how well they know it. In short, give them time to think. Test each sentence for relevancy, and avoid over-fussy qualifications and reservations. In scientific writing, everyone has to compromise between over-simplification and writing nothing at all.

Presentation

The number of illustrations will vary according to the subject, and the author should ascertain from the officials whether an epidiascope or other projector will be available. Check on this a few days before the meeting, to avoid the possible disappointment of arriving with carefully arranged illustrations only to find that the hall has not been blacked out.

In many societies, where the papers are printed and circulated in advance, the author is not expected to read the whole, but to give an introductory talk lasting from ten to twenty minutes. The psychological function of this is to call to the minds of the audience many of the associations which will be required later. The introduction may very well take the form of a summary of the present state of knowledge in the field, followed by the main conclusions of the paper. Do not attempt to develop the arguments upon which these conclusions are based. The introduction also provides a last chance to steer the following discussion towards the subjects in which the author is particularly interested.

Questions may be answered singly or *en bloc* at the end of the discussion period. The former method is usually adopted at informal meetings, but a combined reply is often given when contributors present prepared statements on the subject of the paper. The combined reply is preferred by authors who are not adept at giving snap answers, and often it is possible to save time by covering several questions with one reply. Questioners are inclined to run to words, and it will be found that twenty minutes at the end of the session is ample time in which to answer the principal points made.

F. J. Edwards' Irish Agents

F. J. Edwards, Ltd., have changed their representation in Eire, their agents in that country being Hendron Brothers (Dublin), Ltd., 37–39, Upper Dominick Street, Broadstone, Dublin. (Tel.: Dublin 41116/9).

Hardness and Microstructure of an Alpha-Beta Titanium Alloy Quenched from Temperatures in the Range 600°—1,000° C.

By A. Greenwood, A.Met., A.I.M., and W. Evans, B.Sc.

Metallurgical Laboratory, The Fairey Aviation Co., Ltd., Hayes, Middlesex.

A commercial alpha-beta titanium alloy quenched from temperatures in the range 600°–1,000° C. showed a minimum hardness at 700° C. and a progressive increase to 950° C. Beta grain growth occurred after completion of the alpha-beta transformation and a limited amount of reversion of beta to alpha took place on quenching.

IN the course of an investigation of the properties of titanium alloys, a commercial *alpha-beta* alloy was heated to temperatures within the range 600°–1,000° C. and quenched in water, prior to hardness testing and microscopic examination. The alloy, Ti-175A, supplied as centreless-ground ¾ in. diameter wrought bar by the Titanium Metals Corporation of America, contained both *alpha* and *beta* stabilisers, and had a nominal composition of chromium 3%, iron 1·5%, oxygen 0·5%, nitrogen 0·04%, tungsten 0·08% max. and carbon 0·02%. Small pieces of the bar were placed in an electric muffle furnace and heated in air for 45 minutes at temperatures within the above range before quenching in cold water. The preparation of the samples for hardness testing and metallographic examination included the removal of at least 0·050 in. from one transverse face before polishing.

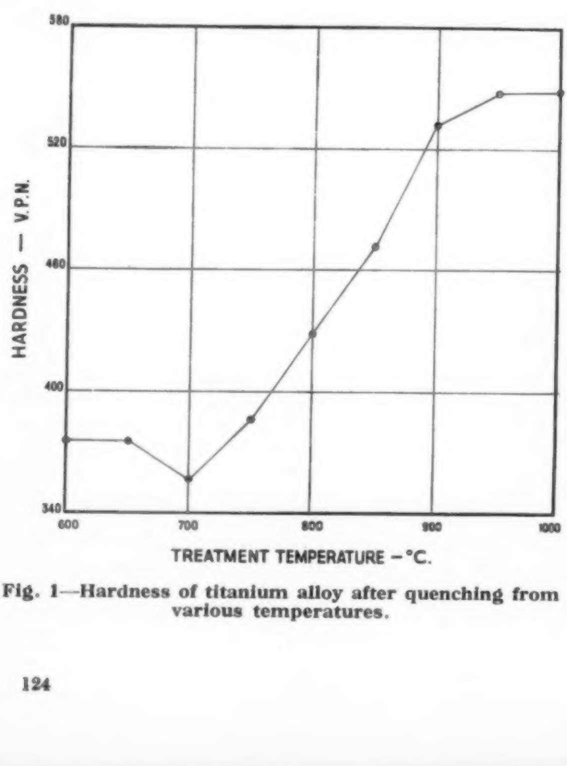


Fig. 1—Hardness of titanium alloy after quenching from various temperatures.

TABLE I.—HARDNESS OF TITANIUM ALLOY AFTER QUENCHING FROM VARIOUS TEMPERATURES

Treatment Temperature* (°C.)	Average Hardness V.P.N./5
" As received "	361
600	376
650	376
700	357
750	386
800	429
850	472
900	532
950	547
1,000	549

* Specimens kept at temperature for 45 minutes and quenched in cold water.

Hardness Testing

Hardness tests were made on the Vickers diamond pyramid machine, using a load of 5 kg., a number of impressions being made on each sample. The average hardness of each specimen was then evaluated and plotted against the temperature of treatment. The results are set out in Table I, whilst Fig. 1 shows the curve relating hardness to treatment temperature.

The " as received " material had a hardness of 361 V.P.N., and heating at 600° C. and 650° C. increased it slightly, whilst a 700° C. treatment resulted in softening. As the treatment temperature was raised from 700°–950° C., the resulting hardness increased steadily from 357–547 V.P.N., but no further appreciable increase was detected after heat treatment at 1,000° C.

Metallographic Examination

Metallographic specimens were prepared by hand grinding on emery papers to grade 0000, followed by polishing on broad cloth impregnated with coarse alumina, the final polish being obtained with broad cloth and fine alumina. After microscopic examination in the unetched condition, the specimens were etched in an aqueous solution containing 7% nitric acid and 3% hydrofluoric acid before examination by normal illumination and by polarised light.

This examination showed that after heating for 45 minutes at temperatures up to 800° C., no significant change had occurred, the resulting structures resembling those in the " as received " condition (Fig. 2). As the treatment temperature was raised above 800° C., an

Fig. 2

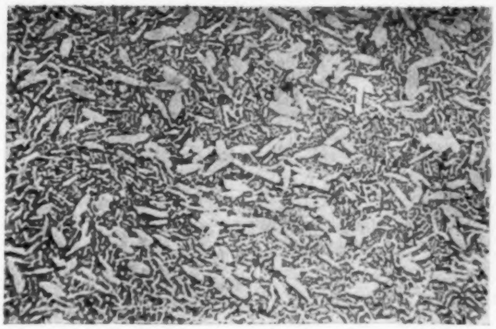


Fig. 3

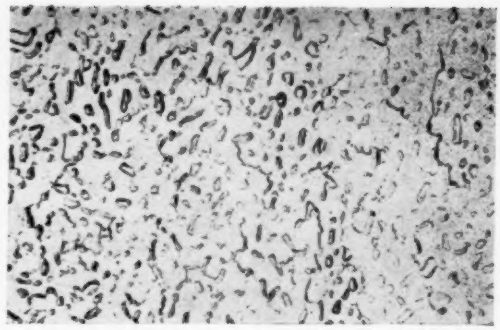


Fig. 4

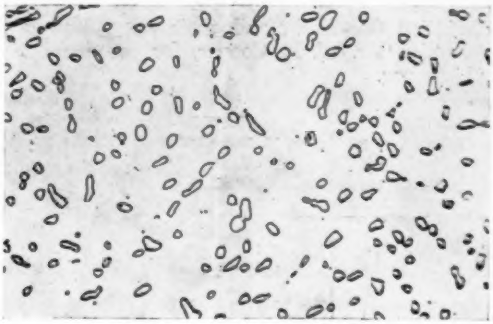


Fig. 5

Fig. 6

Fig. 7

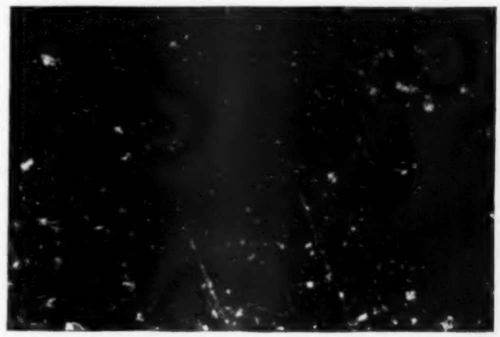


Fig. 8

Fig. 9

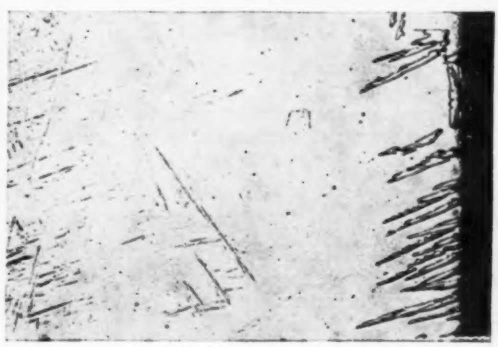


Fig. 2—" As received " material. × 500
Fig. 3—Quenched from 850° C.—alpha in beta matrix. × 500
Fig. 4—Quenched from 900° C.—decreasing quantity of alpha. × 500
Fig. 5—Quenched from 1,000° C.—large beta grains. × 25
Fig. 6—Quenched from 950°C.—untransformed massive and acicular alpha in beta matrix. × 500
Fig. 7—Quenched from 950° C.—similar field viewed under polarised light. × 500
Fig. 8—Quenched from 900° C.—variation in alpha concentration. × 500
Fig. 9—Quenched from 1,000° C.—untransformed alpha needles at the surface. × 100

increasing amount of the *alpha* constituent was transformed (cf. Figs. 3 and 4). The grain-growth inhibiting effect of the *alpha* phase was shown by the rapid *beta* grain growth which occurred after the *alpha* to *beta* transformation was completed (Fig. 5). The cooling of the specimens quenched from 950° C. and 1,000° C. was not sufficiently rapid to ensure the retention of the *beta* grains in a completely unchanged condition. The product of the *beta* to *alpha* transformation appeared as an acicular metallographic constituent, which increased in size and quantity with increase in heat treatment temperature (Figs. 6 and 7).

Examination of the surfaces of the specimens showed the *alpha*-stabilising effect of oxygen and nitrogen. Heat treatment at 900° C. had resulted in sufficient absorption and diffusion of these gases to form in the surface regions an oxygen/nitrogen rich alloy having a higher transformation temperature than the uncontaminated material[1,2] (Fig. 8). At 1,000° C., penetration had been much deeper, and the treatment had been such as to transform all the *alpha*, with the exception of elongated *alpha* grains at the surface of the specimen (Fig. 9).

Phase identification was simplified by examining the specimens under plane polarised light whilst rotating them about the optical axis of the microscope. When examined in this way, the cubic *beta* phase remained dark all the time, whilst the acicular *alpha* showed the most pronounced degree of difference, and the massive *alpha* changed colour from pale grey-blue to orange-red. Phase identification of fine structures proved difficult. In all instances, the flowed layers were removed by light etching from the surfaces of the specimens before examination under polarised light.

Acknowledgments

The authors wish to thank the Directors of Fairey Aviation Co., Ltd., and their Chief Metallurgist and Chemist, Mr. W. E. Cooper, for permission to publish this paper.

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Tonnage Oxygen for Flash Smelting

THE only one of its kind in Canada, a tonnage oxygen unit for producing the vast quantities of oxygen required for the direct flash smelting of copper concentrates has been put into operation at Copper Cliff, Ontario, by The International Nickel Company of Canada, Ltd. Inco's new oxygen flash smelting process eliminates the fuel normally required for smelting, and makes economical the present large-scale output by Canadian industries of liquid sulphur dioxide from furnace exhaust gases.

International Nickel's operations call for a volume of more than 7,500,000 cu. ft. of oxygen every day—enough to fill 32,000 standard cylinders. This requires the production of 300 tons of 95% purity oxygen every 24 hours. The oxygen plant, designed and built for International Nickel by Canadian Liquid Air Co., Ltd., and known as an Oxyton, separates the oxygen from atmospheric air by the liquefaction process, using the same basic principles as apply in smaller commercial oxygen plants. The air is first liquefied under pressure in a series of compressors, regenerator-heat exchangers, distillation columns and other equipment, and then the oxygen is separated from the other constituents of the atmosphere—nitrogen, argon, neon and krypton. The oxygen is carried as a gas through a 16 in. diameter elevated pipeline from the Oxyton to the smelter, a distance of 6,000 ft.

As very low temperatures are involved in the liquefaction process, special consideration had to be given to the metals and other materials employed in certain parts of the oxygen generating unit. For example, the important regenerator-heat exchanger system consists of two nitrogen regenerators, each 8 ft. in diameter and 17 ft. long, and two oxygen regenerators, each 4 ft. in diameter and 14¾ ft. long. While one pair of regenerators chills the incoming air, the other pair is being chilled by the separator gases. Working temperatures range from 80° F. to —280° F. Since most ferrous metals suffer a marked increase in brittleness at sub-zero temperatures, the regenerators were made from special 8½% nickel steel, developed by International Nickel for low temperature use. Incidentally, the regenerators are of welded fabrication, type 310 stainless steel electrodes being employed.

Two other interesting pieces of equipment in the oxygen plant are a specially-built oxygen compressor, and a huge turbo-compressor (required for the initial compressing of the air), one of the largest of its kind in the world. Despite its size and intricacies, the operation of the Oxyton is essentially automatic, once the liquefaction process has been started. Control and metering are carried out by modern electronic equipment with over 40 control instruments centralised on a huge operating panel—the nerve centre of the plant.

The far-reaching possibilities of large scale oxygen applications in the metallurgical and chemical industries have been recognised within recent years by leading scientists. Their studies lead to the conclusion that oxygen, employed in tonnage volumes, will transform many industrial processes within the next generation.

A.C. Mine Winders

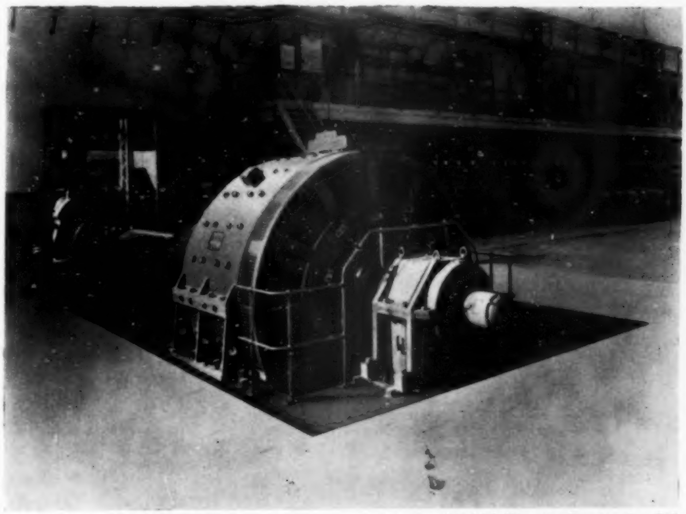
OF late, the development of dynamic braking has led to the increased use of A.C. induction motors for driving large mine hoists. A recent example is the 4,500 h.p. equipment installed at the No. 1 shaft of the Virginia Gold Mining Co. in the Orange Free State, which is one of three similar winders supplied by Metropolitan-Vickers to the Anglo-Transvaal Consolidated Investment Co., Ltd. This installation comprises a 14 ft. diameter double-drum winder driven through gears by two 2,250 h.p. (5,625 h.p. peak), 490 r.p.m., 6,600 volt, type AIF induction motors; it is equipped with the latest M.-V. transductor controlled dynamic braking.

An interesting lay-out is employed in this installation, all the auxiliary equipment for the control of the winder being assembled on a single "winder auxiliaries control board." This arrangement lends itself to a neater lay-out of the equipment in the winder house, and it also cuts down the external cable connections between various items of equipment.

Electrical Plant for the Metal Industries

Progress in 1953 Reported

FOR many years now, the electrical industry has played a major part in the provision of equipment for the metallurgical and metal-using industries. Electrical drives for rolling mills—whether as new construction or for the modernisation of existing mills—undoubtedly constitute one of the outstanding applications of electricity in this field, but a considerable volume of business concerns the smaller motors, switchgear, and, more recently, electronic-control equipment. Some idea of the extent to which metal working depends on electricity may be gained from the following information, which has been extracted from surveys of the activities of a number of the large electrical engineering concerns during 1953.



Courtesy of British Thomson-Houston Co., Ltd.

2,800-h.p., 65/130 r.p.m reversing D.C. motor driving hot-finishing mill for stainless steel strip plant at Shepcote Lane Works, Sheffield.

British Thomson-Houston Co., Ltd.

Rolling Mills.

The year has seen the completion of the large reversing mill modernisation scheme at Round Oak Steel Works. For this scheme, B.T.H. has supplied one reversing cogging mill equipment with a 4,000 h.p. (cut-out 12,000 h.p.), 50/120 r.p.m. D.C. motor; one reversing section mill equipment with a 4,000 h.p. (cut-out 12,000 h.p.), 72/180 r.p.m. D.C. motor; and a reversing billet mill equipment, also with a 4,000 h.p. (cut-out 12,000 h.p.), 72/180 r.p.m. D.C. motor: the motors are supplied from two flywheel motor-generator sets. The cogging and section mill motors were put into operation in previous years and the billet mill equipment was started up in 1953.

A further drive put into operation last year includes two 1,250 h.p., 187·5/375 r.p.m., 500 volt D.C. motors, supplied from a 2,000kW. grid-controlled mercury arc rectifier consisting of four pumpless steel tanks. This drive is for the fourth stand and edger stand of an existing continuous billet mill at Messrs. Stewarts & Lloyds, Ltd., Corby.

A 10 in. finishing mill supplied through the Brightside Foundry & Engineering Co., Ltd., to Swift Levick & Sons, Ltd., Sheffield, incorporates a B.T.H. 350 h.p., 350/840 r.p.m. D.C. motor, together with a 280 kW. pumpless steel tank rectifier, transformer, and incoming Class AJ 21 switchgear.

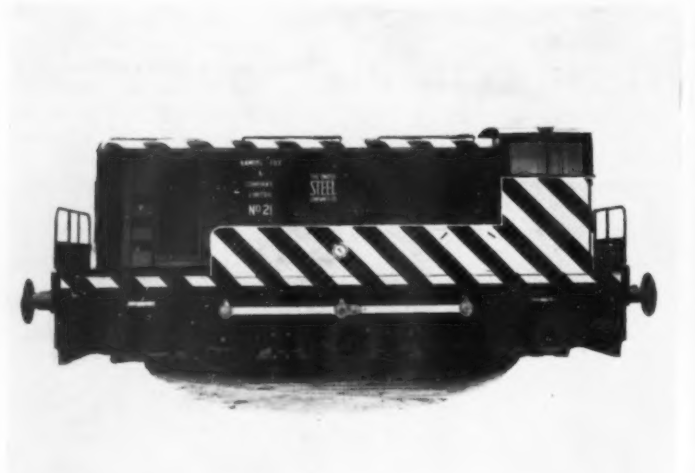
Electrical equipment for driving a 4-high foil mill is being installed in the London area. The main drive of the mill is by a 300 h.p., 535/1,070 r.p.m. motor, the reel and feed reel each being driven by two 25 h.p., 400/1,050 r.p.m. motors in tandem. Also included are the motor-generator sets, open-type control panels, and amplidyne equipment for control of foil tension. When in service this mill will be capable of reducing 32 in. wide foil from 0·44 mm. to 0·045 mm. in three passes at roll speeds up to 2,000 ft./min.

New orders of considerable value have been placed with B.T.H. during the year, the most important being the electrical equipment for a 5-stand tandem cold tinplate strip mill for The Steel Company of Wales' new plant at Velindre, South Wales. It is similar to the Trostre equipment, and comprises the following D.C. motors: one 1,750 h.p., two 3,500 h.p., one 4,000 h.p., one 5,500 h.p. and one 900 h.p.; all are supplied from two synchronous motor-generator sets. The equipment includes a large section of contactor panel and the control embodies a combined use of amplidynes and magnestats. The mill has the exceptionally high speed of 5,000 ft./min.

Another important order concerns the electrical equipment for a continuous merchant bar mill for the Broken Hill Pty. Co's. new plant at Kwinana, Western Australia. The equipment includes six 600 h.p., 200/600 r.p.m. D.C. motors, supplied from a 3,000 kW. synchronous motor-generator set, together with associated control gear.

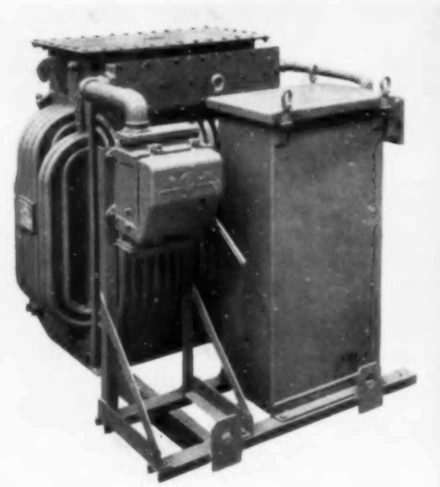
A small mill drive has been ordered by Guest, Keen & Nettlefolds (South Wales), Ltd., for a temper pass mill. The mill will be driven by an existing 250 h.p. D.C. motor taken from the same customer's tandem cold strip mill, this motor being replaced on the tandem mill by a new 350 h.p., 300/800 r.p.m. D.C. motor. A new motor-generator set and 60 h.p. reel motor are being supplied for the temper pass mill, and the equipment also includes control gear and amplidyne control for constant strip tension.

An order has also been received from Stewarts & Lloyds, Ltd., Corby, for the electrical equipment for a Fretz Moon Mill to be installed by the Indian Tube Co., Ltd., Jamshedpur. The equipment comprises an 8-way main A.C. switchboard consisting of 30 MVA. Class QA gear, a 4-panel open type D.C. distribution board, A.C. and D.C. motors, and an open-type contactor control board approximately 90 ft. in length.



Courtesy of the Yorkshire Engine Co., Ltd.

400-h.p. three-axle diesel-electric shunting locomotive for steelworks use. B.T.H. were responsible for the necessary electrical equipment.



Courtesy of English Electric Co., Ltd.

300-amp. 12-operator welding transformer complete with capacitor and fuse-switch, all mounted on common underbase

Steel Works Auxiliaries.

The first of the nine hot dip tinning lines being installed at the Trostre Works of The Steel Company of Wales was commissioned last June. These lines are driven by shunt controlled D.C. motors overhung from B.T.H. double-reduction helical gearboxes. Auxiliary drives employ totally-enclosed, fan-cooled, squirrel-cage motors, and cubicle type control panels are used throughout. The lines are capable of processing steel sheets which vary from 19½ in. to 38 in. in length and from 38 to 20 gauge. The maximum speed of the line will be 300 ft./min.

A further interesting order has been received from The United Steel Companies, Ltd. (Steel, Peech & Tozer Branch), covering electrical equipment for snap shears and rotary dividing shears. The rotary dividing shears are driven by shunt controlled D.C. motors, while the snap shear is controlled by solenoids. Also included are open-type control panels, sheet steel control desk, and photo-electric equipment which will enable the length of cut bar to be controlled within very fine limits.

Electric Furnaces.

In addition to maintained demand for amplidyne regulators for melting arc furnace electrode control, B.T.H. has received from Birlec, Ltd., an interesting order for the electrical equipment involved in a scheme for electrode control of two 7,500 kVA. ferro-silicon smelting furnaces for Messrs. Ferro-metals, South Africa; B.T.H. will be supplying amplidyne control equipment for controlling the 10 h.p. pump motors operating the hydraulic electrode-platform raising and lowering mechanism.

Further orders have been received for motor-generator equipments for high-frequency induction melting and heating plant, in all cases the high-frequency generators being excited and voltage controlled by Type FV thyratron voltage regulators. Two 750 kW. 1,000 c./s. synchronous motor-generator substation equipments for Birlec 30 cwt. high-frequency melting furnaces have been installed and commissioned in 1953, and the whole plant is now operating in the production of special alloys at Henry Wiggin's new Hereford factory.

Interesting high-tension control equipment has been introduced for arc furnace operation, which consists of two cubicles, one of which is used to house an oil circuit-breaker for back-up protection, and the other for a high-tension contactor capable of frequent operation as required in general arc furnace duty. The circuit-breaker equipment can be withdrawn for isolation.

Sinter Plant.

The United Steel Companies are extending their sinter plant at Scunthorpe, known as the Seraphim project, to increase the treatment of indigenous iron ores. For this project B.T.H. has supplied a large number of motors, two 127 kW. motor-generator sets, and the main control equipment. B.T.H. is also supplying electric equipment for blast furnaces for Ashmore, Benson, Pease & Co., Ltd., and for grabbing and overhead travelling cranes for Joseph Booth & Bros., Ltd.

Electronics.

Welding Control.—The development of a new type of B.T.H. electronic control for seam and spot resistance welders was mentioned in the last annual review. These new types of control are now in the production stage and delivery will be available in 1954. Unlike welder controls hitherto available, the new device makes a direct count of the number of cycles of power delivered to the resistance welder. " Dekatron " counting tubes are used, and a visible digital indication of the weld period is displayed.

A new type of flow and pressure switch has now been completed, specially for resistance welders ; the design has been simplified while retaining the sensitivity of the former model.

Photo-electric Equipment.—As a result of the increased use of photo-electric control in steel works, it has been necessary to introduce a heavy duty photo-electric cell-holder, capable of withstanding misuse, and water-cooled to permit installation near radiant metal.

An improved model of the photo-electric pinhole detector, for giving warning of holes 0·01 in. diameter in steel strip travelling up to 1,000 ft./min., has been produced. Improved mechanical construction has been necessary together with better air cleaning devices for a sensitive system which is installed in contaminated atmospheres.

Steelworks Locomotives.

The supply of electrical equipment for the Ruston-B.T.H. 155 h.p. diesel-electric works shunting locomotives has continued steadily throughout the year, and altogether 26 equipments have now been ordered. More equipments have also been supplied to the Yorkshire Engine Co. for their 275 h.p. standard steelworks shunter, of which 19 sets of equipment have now been ordered. Several of these locomotives are now in service in steelworks in various parts of this country. The first of two 400 h.p. 3-axle locomotives, also equipped by B.T.H. has been completed at the Yorkshire Engine Co's. Works and has undergone its trials.

Magnetic Amplifiers.—Magnetic amplifier (magnestat) development has continued throughout the year, mainly in connection with regulators. In addition, however, work is now proceeding with larger magnestats having outputs up to 3 kW. It is intended that these static devices shall replace the smaller ratings of amplidyne generator, particularly in steel mill applications.

Crane Communications.—There are many industrial processes in which a reliable system of communication is required between fixed control points and moving vehicles such as trolley-wire locomotives and overhead cranes. Radio transmission is often undesirable, both on technical and licensing grounds, but in the majority of cases it has been found possible to provide a satisfactory carrier communication channel over the existing power system cables and trolley wires. Satisfactory demonstrations have been made in the Rugby Works, and orders are in hand for ten installations in a variety of steel mills, melting shops, and coke oven plants. Well-known customers are United Steel Companies, Consett Iron Company, Ministry of Supply, and Dorman Long.

English Electric Co., Ltd.

Rolling Mills.

During 1953, many orders have been received for steelworks electrification plant, and interesting equipment has been put into service.

Among the various orders received during 1953 are two important cold mill drives for South Wales, both for the Ebbw Vale works of Richard Thomas & Baldwins, Ltd. The first of these involves the complete main drive electrification of a 5-stand cold mill for rolling steel strip up to 38 in. wide, and up to a speed of 5,000 ft./min. (57 m.p.h.). (This mill will be one of the fastest of its type in Europe.) The aggregate horsepower is 19,150 r.m.s., the main motors being supplied from two motor generator sets, each driven by a 9,000 h.p. synchronous motor. The second of these cold mill orders comprises the main drives for a 2-stand temper mill, which further processes the strip from the 5-stand cold mill. The mill rolls the strip at 4,000 ft./min. (45 m.p.h.) and will be one of the fastest mills of its kind in the country.

Among the hot mill drive orders received during the year, is a 9,200 h.p., 40/80 r.p.m. (492 metre-tons torque) drive for a 190 in. plate mill in Scotland. On this mill, the two work rolls will be driven by separate motors. Output is obtained by means of two motors, the upper motor driving above the lower motor through a long jack shaft.

The export orders received during 1953 include a large one from Spain, comprising complete main and auxiliary drives for a hot blooming mill and two structural mills. This order comprises three main mill drives, totalling 20,440 h.p., r.m.s., one of the drives being a 7,000 h.p. unit with twin motors.

Among jobs commissioned, is a set of reversing mill control gear, which completely modernises and controls equipment obtained under reparations from Germany.

A 17-stand rod mill has been put into service in the Sheffield area. This mill rolls rod at the maximum speed of approximately 3,000 ft./min., and has a very modern control scheme, involving electronic equipment, together with two flying shears. The aggregate horsepower of the main drives is 8,225 r.m.s. and the power for the main D.C. motors is obtained from two motor generator sets, each driven by a 4,400 h.p. motor.

A further rod mill, having 18 stands and powered by main D.C. motors, deriving power from two 2,000 kW. pumpless type rectifiers, has been commissioned at one of the works of the Lancashire Steel Corporation, Ltd. This mill is of the well-known Morgan type and rolls at speeds of up to 4,000 ft./min., two strand. A hoop mill, involving two intermediate, two edger, and three planishing stands, was commissioned at Barrow. This mill has a special speed matching control, which automatically ensures loop control between stands.

Among jobs commissioned abroad is a large push bench equipment for Brazil, for the manufacture of seamless steel tubes up to 5 in. diameter, and at the rate of 210 tubes per hour. The push stroke of the bench is 600 ft./min. and the return stroke 1,000 ft./min. The main motor is 4,500 h.p. (cut-out), at 103 r.p.m., and is of double armature construction, to permit low inertia. The order also covers A.C. distribution plant, transformers, and many auxiliary drives. In Australia, a large reversing mill has been commissioned, having an r.m.s. output of 7,000 h.p. at 50/120 r.p.m. (300 metre tons cut-out torque), which duplicates similar equipment already supplied to the same customer.

A very interesting planetary hot strip mill, the only one of its type in Europe, was also commissioned. With this type of mill, in the place of the normal work rolls, there are two rolls surrounded on their periphery by many small diameter rolls, each mounted in its own bearings. The particular advantage of this arrangement is the extremely large reduction possible, a typical figure being $1\frac{1}{2}$ in. down to 0·05 in. in one pass, the strip then being ready for coiling.

Mercury Arc Rectifiers.

Among the interesting rectifier equipments put into service during the year were two 1,650 kW. sets feeding the main motors of the new rod mill at the Warrington Works of the Lancashire Steel Corporation, Ltd.; these sets include grid control for motor starting and fine speed control, while a wide range of speed control is given by on-load tap-changing on the transformers.

Other equipments commissioned include two 3,300 kW. sets feeding the main motors of a new billet mill at the Consett Iron Company's Works, and two 4,200 kW. sets feeding D.C. motors in the engine test plant of the

Bristol Aeroplane Co., Ltd. Both the Consett and Bristol equipments include grid control for motor starting and speed variation.

Industrial Electronics.

Several large contracts, in which electronic control plays a vital part, have been brought to a successful conclusion, while work has commenced on new industrial projects. The new 10 in. continuous bar rolling mill of Parkgate Iron & Steel Co., Ltd., has been equipped with complete electronic control. This synchronises the speed of the many stands, measures the length of the bar to be cut, and operates the flying shear or coiler. The mill has already attained a record output and gives every evidence of future success.

Standard controllers, with improved performance, from f.h.p. to 100 h.p., continued in production, speed accuracy within 0·1% being offered in certain applications, while, for simplified controllers, 5% accuracy is normal.

A complete range of H.F. induction heaters has been developed, backed by an applications service which will ensure their being used with maximum efficiency.

Welding Plant.

During 1953, the demand for the English Electric standard A.C. single and multi-operator arc-welding units, as well as for the newly-developed welding electrodes, continued. The redesigned portable units, embodying the experience gained by the Company in the welding field, were shown during the year. Their operation and appearance have been very favourably received.

The multi-operator arc-welding units, particularly when mounted on an under-base, with a capacitor and a fuse-switch, have proved popular. A typical unit is the 300-amp, 12-operator transformer, with capacitor and fuse-switch illustrated. The 600-amp portable welding unit is representative of the new range of apparatus.

Miscellaneous.

Six A.C./D.C. motor generator sets, each consisting of four 1,500 amp. generators and a driving motor, are on order for a plant which will produce sponge titanium in large quantities.

The General Electric Co., Ltd.

Rolling Mills.

The successful operation of the two 2-stand temper mills at the Trostre Works of the Steel Company of Wales has resulted in a new contract being placed for the electrical equipment for two further temper mills to be installed in the Velindre Works, near Swansea.

These mills are 42 in. wide, operating at strip speeds up to 4,000 ft./min., and the electrical equipment will be generally similar to that installed in the Trostre Works. Each stand will be driven by a 1,000 h.p., 600 volt motor running at 700/950 r.p.m.: the uncoiler and coiler motors are each rated at 300 h.p. and those for the top and bottom tension rolls at 500 h.p. and 250 h.p. respectively. Power for the mill will be provided by a 5-machine motor-generator set and full use will be made of control exciters. Also for the Steel Company of Wales, a further 114 mill type motors, ranging from 7½ h.p. to 200 h.p. and totalling over 7,500 h.p., are being supplied in connection with the new development scheme.

At the Whitehead Iron & Steel Co., Ltd., a 24 in. skin pass mill has been commissioned. The stand motor is rated at 200 h.p. and the coiler motor at 150 h.p., the mill being Ward-Leonard controlled. Constant tension is preserved by the cascade exciter system of control which provides accurate compensation for coil build up.

Three fully automatic drawbenches, one of 300,000 lb. and two of 100,000 lb. capacity each, are now in operation at the Kirkby Works of the Metals Division, I.C.I., Ltd. For the larger drawbench, the main driving motor is rated at 1,000 h.p. while the motors for the two smaller drawbenches are each rated at 450 h.p. Grid-controlled mercury arc rectifiers provide the power for these machines, the speeds of which are automatically controlled. The auxiliary motors, which range from 1 to 65 h.p. are supplied from a tertiary winding on the main rectifier transformer, each drawbench being supervised from its own control desk. A similar equipment of 100,000 lb. capacity has also been supplied to Metal Manufacturers of Australia, Pty., Ltd.

A new range of mill type motors, series M, is now in production. These machines are available in 11 frame sizes with outputs ranging from 5 h.p. to 200 h.p., and comply fully with the dimensions and ratings standardised by the American Association of Iron and Steel Electrical Engineers, Standard No. 1, dated September, 1947. The motors are specially designed for quick starting and stopping and are fitted with fans mounted on the armature shaft to circulate the air through the core ducts and between the field coils. The construction is particularly robust to withstand the severity of service encountered in auxiliary drives in steelworks.

Materials Handling Equipment.

An order has been received for iron ore handling plant to form part of the Seraphim extension of the Appleby-Frodingham Steel Co. Conveyors are also being supplied for the sinter plant for the same extension, to the order of Head, Wrightson & Co., Ltd., the total length of these being no less than 3¼ miles. In addition, a 60 ton capacity Fraser & Chalmers Marshall side-discharging wagon tippler is included in the contract to the order of Ross Engineers, Ltd. This design has been developed to meet the need of steelworks for a robust high capacity tippler. Two further similar tipplers are in course of manufacture to the order of Ross Engineers, Ltd., for the extensions at the South Durham Iron and Steel Works at West Hartlepool.

The coal blending and handling plant supplied to John Summers & Sons, Ltd., at Shotton, Flint, to the order of Simon Carves, Ltd., is now in commercial operation with satisfactory results, and a further wing tripper has been ordered to increase the capacity of the plant.

At Aviles, Northern Spain, a complete new steelworks is in course of construction by Empresa Nacional Siderurgica S.A., which when completed will be the largest in Spain. The Erith Works are supplying, to the order of Head, Wrightson & Co., Ltd., the iron ore preparation and blending plant comprising crushing and primary screening equipment, from which the ore is conveyed to the blending plant equipped with two wing trippers and two Robins Messiter blending machines. After blending, the ore passes through the secondary screening station and from there is conveyed to the furnace bins.

In the survey for 1952, reference was made to a large iron ore preparation plant on order for Kapitalna Iron Works, Zenica, Yugoslavia. This plant is now in course of erection and an order has been received for extensions comprising conveyors for handling ore and sinter to the third blast furnace.

Other orders received include a coke handling plant for United Coke & Chemicals Co., Ltd., at Orgreaves, Sheffield.

Ore Crushers for Sinter Plant.

For the Appleby-Frodingham Steel Co., Scunthorpe, a contract is in course of execution for six special hammer mills, each weighing 18½ tons, to carry out the final crushing of iron ore for sintering. The final design of the machines has been developed at Scunthorpe over the past 12 months, by experiments with a modified existing unit. The duty required of each mill is to reduce iron ore from ¾ in. to ¼ in., at the rate of 120 ton/hr., and the condition of the material varies with the weather conditions from being almost bone dry to a consistency approaching that of wet clay. The problem was to produce a machine to operate with a minimum of dust nuisance when working on dry ore, and to prevent plugging up when crushing wet material.

Three existing hammer mills supplied from the United States and embodying a moving front plate were not satisfactory, as they required cleaning of built-up material two or three times in every shift. An additional moving plate travelling round two sprocket shafts was added to the rear of one of the existing mills and, after a full series of experiments and alterations, a successful arrangement was decided upon.

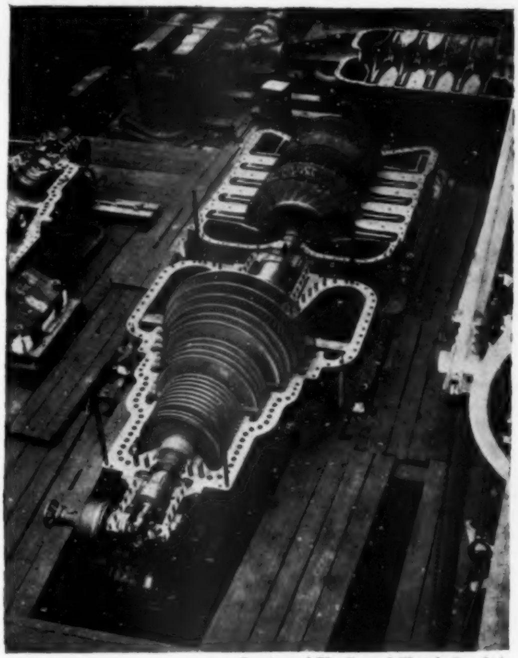
The six new machines are an improvement on the original prototype, in that a maximum of accessibility has been achieved which, together with special feeding and discharge features, should go a long way towards solving the age-old difficulty of treating damp and sticky materials.

Induction Hardening Equipment.

A recent addition to the range of special purpose high frequency heating equipment is a machine for surface hardening steel bars of ½ in. to 1¼ in. diameter in a continuous operation. The bars are placed one at a time at the top of an inclined V-slide, down which they pass through the heating coil and then through the quench box, afterwards sliding down a chute into a collection basket. Two driven V-rollers, one above and one below the heating coil and geared together, accurately control the speed at which the bars are allowed to move. By altering the speed, the thickness of the hardened case may be varied and skin thicknesses of 0·02 in. to 0·1 in. are obtainable in this way. Power, provided by a 25 kW. high frequency generator, is concentrated into a short axial length of bar surface, causing rapid heating to hardening temperature. The machine will harden 1 in. bars to a depth of 0·04 in. at a speed of 30 in. a minute.

Generators and Compressors.

Recent orders for industrial generating plant include three 10 MW., 11 kV. sets for Colvilles; a 15 MW. set for installation at the Cleveland Iron Works of Dorman Long & Co., Ltd., and a 5 MW. set for Guest Keen & Baldwins Iron & Steel Co., Ltd. The last named machine is required to supply process steam at a pass-out pressure



Courtesy of The General Electric Co., Ltd.

Turbo-blower for Dorman Long's Cleveland Works during manufacture

of 155 lb./sq. in. and is to be used in their East Moors Works, Cardiff. Other sets recently commissioned include a 6 MW., 11 kV. unit for Sheepbridge Iron Co., Ltd., operating at a steam pressure of 600 lb./sq. in., 800° F., and passing out 56,000 lb./hr. of steam at 165 lb./sq. in.; and a 7·5 MW., 2·75 kV. high-pressure turbo-alternator for the Skinningrove Iron Co., Ltd.

At the Cleveland Works of Dorman Long & Co., Ltd., a further turbine-driven blower has been installed to deliver 90,000 cu. ft./min. of air at a pressure of 30 lb./sq. in. gauge.

Transformers—Reactors—Rectifiers.

Two 20 MVA, 33/6 kV. transformers, which form part of an important extension to the electrical plant at the Whitehead Iron & Steel Co., Ltd., and six of the twelve 4,140 kVA. furnace transformers for Albright & Wilson, Ltd., are now installed. The latter are arranged to operate in pairs, each pair supplying a 6-electrode type phosphorous furnace.

The seven outdoor reactors involved in the Whitehead scheme are in service, six with a 3% reactance on a throughput of 4,600 kVA., and the seventh with a reactance of 1·5% on a throughput of 4,000 kVA.

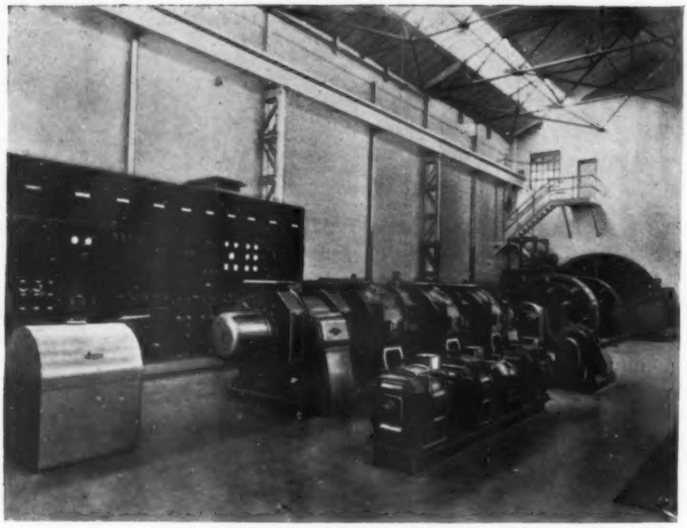
In the multianode rectifier field repeat orders have been placed by The Steel Company of Wales, Ltd., and the Appleby Frodingham Steel Co., the former covering a 1,600 kW., 400 volt equipment, and the latter, two 500 kW., 230 volt equipments.

Metropolitan-Vickers Electrical Co., Ltd.

Rolling Mills.

Many main and auxiliary drives have been commissioned on rolling mills during 1953, and others are being erected or are on order.

The drive for a 32 in. reversing blooming mill drive of 4,000 h.p., 50/120 r.p.m., for the Llanelly Steel Co.,



Courtesy of Metropolitan-Vickers Electrical Co., Ltd.

4,000 h.p., 50/120 r.p.m. reversing drive for a 32in. blooming mill at the works of the Llanelly Steel Co., Ltd.

Ltd., is supplied from a flywheel motor generator set under full Ward-Leonard control. The flying billet shear, which is driven by two 200 h.p. steelworks motors (type MDX) is controlled on the metadyne Ward-Leonard principle, and is designed to shear accurately "on the fly."

In the new laboratories of the British Iron and Steel Research Association an important unit is a 14 in. single-stand reversing strip mill, for which M-V supplied the electrical equipment. This mill, which is designed for the experimental rolling of various metals, will operate at strip speeds up to 1,750 ft./min. and has many unique features to enable accurate data to be obtained. For example it can be used for rolling short lengths of material, stable speed regulation down to about 10 ft./min. being provided by electronic amplifier control, or it can be operated with the rolls lifted, the strip being passed from one reel to the other under tension. The mill is driven by a 750 h.p., 955 r.p.m. D.C. motor, and the two reels by 200 h.p., 119/477 r.p.m. D.C. motors with tension regulation by metadyne magnetic amplifier control.

At the Abbey Works of the Steel Company of Wales the electrical equipment has been commissioned for a single-stand temper mill for coil or sheet rolling, and a cold mill producing special alloy sheets in southwest England has been equipped with a 300 h.p. D.C. motor with preset Ward-Leonard control, and screwdown and auxiliary equipment.

Complete electrical equipment has been supplied for a three-high sheet mill with tilting tables installed at Frederick Braby's works in Glasgow. The mill has automatic screwdown control, working in conjunction with the feeder and catcher tables: the operators depress a foot switch after each pass, and the sequence then follows automatically. In setting up a given programme, any odd number of passes up to nine with provision for match passing may be set up on selector switches, while the roll openings for each pass are set on a multi-circuit vernier-cam limit switch; the rolls reset automatically for each pass.

An 800 h.p. non-reversing non-ferrous strip mill complete with screwdowns and upcoiler has also been commissioned; the screwdown is Ward-Leonard controlled from a three-field generator to obtain inherent load limitation. In South Wales, a 4-stand tandem cold mill rolling steel strip up to 22 in. wide is being erected at the Whitehead Iron & Steel Works. This mill has the stands driven by 1,000 h.p. D.C. motors, a 300 h.p. motor driving the tension reel.

A 2,000 h.p. 125/187 r.p.m. machine driving a 20 in. merchant mill at Colvilles is probably the largest 11 kV. two-speed synchronous induction motor ever made, and two 6,700 h.p. ± 50/120 r.p.m. roughing mill drives for the Continent are equipped with the largest rolling mill motors yet built by M-V.

In the course of erection are three 2,000 h.p., one 1,500 h.p. and one 1,000 h.p. D.C. drives for the production of seamless tube; they are supplied from transformer rectifier equipments with grid control for starting and inching, and a variable compounding feature operating on the grid control circuits. Two of the drives have the flywheels and motors solidly coupled and mounted as one unit between two bearings.

Equipment is in hand for a four-high strip mill in South Wales, which will produce pure aluminium and aluminium alloy strip at speeds up to 1,000 ft./min. The mill motor is rated at 1,000 h.p., 400/800 r.p.m., and the coiling reel motor at 200 h.p., 560/1,300 r.p.m.

An interesting screwdown equipment for a Sheffield armour-plate mill comprises two 100 h.p. motors of the MDX steelworks type. The screwdown will be automatically adjusted to preset roll openings after each pass, the maximum opening being 50 in. with an operating speed of 135 in./min. and a stopping accuracy of $\frac{1}{64}$ in. Coarse and fine "magslips" are fitted at the mill and desk, those at the desk being coupled to indicating dials on which the next roll opening is set; pressing a foot switch causes the magslip error signals, electromagnetically amplified and discriminated, to operate through metadynes, and this accelerates, slows down and stops the screwdowns at the pre-set roll position.

An order has recently been received for the electrical equipment for a large twin-drive blooming mill for Dorman Long, whilst modifications in hand for a 860 h.p. aluminium reversing mill in the Midlands involve the supply of MDX motors totalling 80 h.p. and two 55 kW. generators with metadynes and control equipment for table speed synchronisation. Other recent orders include the complete electrical equipment and ventilation for a 400 h.p., 24 in. edging mill in South Wales and the main drive of a rod mill in the Manchester area.

Export work in progress includes 250 h.p. of drives, from 1 to 75 h.p., for blooming and section mill auxiliaries for Karabuk (Turkey), where they will be associated with two 3,100 h.p. hot reversing mill drives supplied soon after the war. Electrical equipment including switchgear, transformer and reversing contactor gear, is also in hand for a 450 h.p. A.C. drive for an aluminium alloy cold reversing mill in Europe.

Auxiliary Drives.

A steelworks in the northwest is being supplied with electrical equipment for three side-trimming lines designed for coils of 74 in. width and 64 in. diameter and to run at 1,000 ft./min. Each line will have twelve 600 volt D.C. motors : six of 120 h.p., 360/1,200 r.p.m. on coiler and decoilers ; two of 120 h.p., 1,000/1,450 r.p.m. on trimmers ; two of 10 h.p., 600/700 r.p.m. on pinch rolls, and two of 12 h.p., 500/600 r.p.m. on processers. The main motors will be supplied from three 0/200 kW. Ward-Leonard generators, driven by a 540 h.p. induction motor, and the decoilers will operate with automatic strip tension.

For the Trostre Works of the Steel Company of Wales, a third shearing and classifier line has been equipped with Ward-Leonard drives and photo-electric and electronic amplifier equipment for strip control in the looping pits.

Twelve motors, ranging from 7½ to 150 h.p. are in hand for driving cranes at Richard Thomas & Baldwins, Ltd., eight motors from 25 to 200 h.p. for an Ashmore Benson & Pease ore bridge for Colvilles, and six motors from 15 to 85 h.p. for a Wellman Smith Owen ladle crane in a Rhodesian steelworks. Twenty-four standard squirrel cage motors ranging from 3 to 20 h.p. have been ordered by South Durham Steel & Iron Co., Ltd., for use with cranes, conveyors and crushing equipment in a new ore handling plant, and nearly 200 variable speed A.C. commutator motors, type CHT, rated at 5/3 h.p. have been ordered for use on Fraser & Chalmers (S.A.) uranium plants in South Africa.

Blast Furnace Auxiliaries.

Electrical equipment for two fully automatic double-skip blast furnace hoists in the North Wales and Sheffield areas is well advanced ; on these installations (both are repeat orders) uniselector relays are used to increase the operating speed and reduce the size of the control equipment.

Many high voltage rectifier equipments have been supplied for use on Head Wrightson precipitators for blast-furnace gas cleaning ; these equipments are completely metalclad and are suitable for outdoor operation, thus minimising installation costs. A new plant at John Summer's works at Shotton includes high voltage rectifiers of both the synchronous mechanical and selenium iron types. Similar equipments are being installed by Appleby-Frodingham Iron & Steel Co., and orders have been received from John Summers & Sons, Ltd., from Colvilles, Ltd., and for export to Spain. Electrical precipitation equipment is also in hand for electrostatic detarrers for gas undertakings.

Materials Transport.

Head Wrightson steelworks cars—two 50 ton transfer cars, two 35 ton scale cars, and a 60 ton hot-metal ladle car—for John Summer's Shotton steelworks have been supplied with electrical equipment, and as a result of their successful operation, further sets have been ordered for a scale car and a transfer car. Two scale car equipments have been supplied for the Tyne Improvements Commission, and three sets have been ordered for 35 ton Head Wrightson scale cars for Dorman Long & Co., Ltd.

Induction Heating.

Of the larger furnace plants put into commission, the most interesting is a 550 kW., 1,500 c./s. equipment for the melting of alloy steels. Each of two hydraulically tilted induction furnaces, steel-bodied and magnetically shielded, is designed to melt 17½ cwt. of steel in one hour ; the control employs voltage stabilisation by means of series capacitors and automatic power factor correction.

Much experimental work has been done on induction heating. The three-phase heating of large cylindrical charges at mains frequency has been carried out successfully, and for radio-frequency heating interchangeable work coils have been developed with their electrical and water connections combined so that coils may be changed easily. A new laboratory has been equipped for radio-frequency development work and two 10 kW. generators operating at about 500 kc./s. with transformer-operated work coils have been installed.

A 10 kW. radio-frequency melting equipment due for delivery to a Government Department has a hand-tilted furnace mounted on castors and provided with quickly detachable water and electrical connections, together with standby water connections. The furnace, even when hot, may thus readily be removed from its operating position and connected to the standby water supply : the R.F. generator is thus freed for use with other apparatus.

Welding.

Equipment for electric arc welding in an inert gas such as argon has been designed with a view to ensuring economy in the use of gas, tungsten electrodes and electricity, and also to extending the use of existing plant to inert-gas arc welding. Standard A.C. sets have been produced, and a surge injector unit (an E.R.A. development) enables standard transformer sets to be used for inert-gas welding. In automatic arc welding, progress has been made in standardising equipment to permit more flexibility of application and in making the standard equipment suitable for submerged welding by simple adjustment.

There is a steady demand for arc welding equipment, and the range of welding transformers has been extended down to 0·25 kVA. : the design of transformers for rectified current welders is now being investigated. A welding electrode using a 55% nickel-iron core wire has been developed for welding cast iron, and also electrodes for creep resisting steels.

Resistance welding machines now include a 10 kVA. bench mounting machine with a 9 in. throat depth. This is a high speed air-operated spot and projection welder, capable of welding two pieces of 16 gauge mild steel and two pieces of 22 gauge stainless steel, as required in the sheet metal industry ; the standard form of welding time control is a neon timer and contactor fitted in a sheet steel cubicle, but the circuit is arranged to allow the use of either a thyratron timer and mechanical or ignitron contactor or, alternatively, a fully synchronous ignitron control.

In addition to the new type of spot and projection welders, several standard three-phase condenser discharge spot welders have been supplied to the aircraft industry. A contract for 60 kVA. spot welders, 100/150 kVA. roller spot welders and 150 kVA. seam welders, all with constant current panels, for welding jet-engine component parts has been completed, and a repeat order has been received for further roller spot welders. A number of resistance seam welders, designed to specific requirements, have been supplied, one set being for welding longitudinal and circumferential joints of motor car silencers.

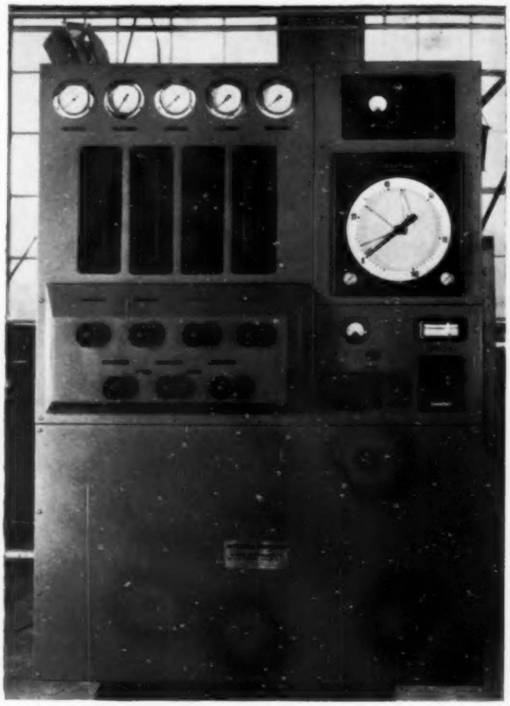
The Nitroneal Generator

A New Apparatus for Producing Protective Gas Atmospheres for the Heat Treatment of Metals

THE vast literature on controlled atmospheres for annealing metals testifies to the great industrial importance of the subject. In general, the ideal atmosphere is one which does not react in any way with the metal and, in the case of certain rarer metals which are now becoming of importance, only the truly inert gases, helium, argon, etc., can be used. For the majority of the common metallic materials used in engineering, however, nitrogen also is inert, and this gas is used on a small scale for heat treatment. The production of oxygen-free nitrogen requires large and expensive plant, and, with a few exceptions, the cost of this gas is prohibitive. In any case, an inert atmosphere only affords complete protection where there is no possibility of the atmosphere being contaminated, either by leakage of air or by evolution of oxygen from refractories or other parts of the vessel in which the heat treatment is being carried out. For this reason it is desirable to provide in the nitrogen a small percentage of a reducing gas such as hydrogen, to take care of any accidental contamination, and such mixtures are ideal atmospheres for many metallurgical heat treatment operations.

Mixtures of hydrogen and nitrogen are, however, used fairly extensively; and a very convenient method of producing such mixtures is by the dissociation of anhydrous ammonia. Ammonia is readily available in a high state of purity, and with exceptionally low water content. It liquefies readily on compression and, therefore, a large quantity can be packed and transported in a steel cylinder. Cracked ammonia is widely used in the metallurgical industry, especially where very high purity justifies the expense. The high proportion of hydrogen (75%) puts it in the same category as hydrogen itself, as regards inflammability and reactivity, and its use is, therefore, limited, both as regards scale of operation and nature of the work being done. To overcome these drawbacks and also to reduce the cost, apparatus has been developed and fairly widely used in which the cracked ammonia is burnt with a slight deficiency of air to give nitrogen containing a small percentage of residual hydrogen. Provided precautions are taken to ensure cleanliness of the air, i.e., freedom from obnoxious impurities such as sulphur compounds, etc., and the burnt gas is thoroughly dried, the resulting hydrogen-bearing nitrogen retains substantially the advantages of the original cracked ammonia without its disadvantages. However, the apparatus required is relatively large and requires close control. Its use is, therefore, economical only where a fairly large and continuous output is required.

A recent development, the Nitroneal Generator,* provides the same sort of atmosphere by combining, in one process, the simultaneous cracking and burning of ammonia. The generator employs a platinum metal catalyst through which a controlled mixture of air and ammonia is passed. The catalyst ensures the complete



reduction of all the oxygen to water vapour, which is then removed partly by condensation and partly by conventional dryers. The dew point of the resulting gas depends solely on the efficiency of drying, and can be reduced to as low as –40° C. without difficulty and even lower if required. The control panel provides for easy adjustment of the ammonia/air ratio and, subsequently, automatic control ensures constant composition. The hydrogen content of the Nitroneal gas can be varied from about 0·25% all the way to 25%, and a built-in analyser indicates and records the hydrogen percentage. The equipment is available in a range of sizes from 100 cu. ft./hr. upwards, and all generators, except the smallest model, are controlled automatically once the orginal setting has been made, i.e., any departure of the analysis from the pre-set figure operates the automatic control. Manual control only is provided on the 100 cu. ft./hr. generator in order to keep down the cost and broaden its field of economic usefulness.

A particularly noteworthy feature is the rapidity with which the generator can be brought into service. It is claimed that from a cold start, a satisfactory atmosphere is produced in about 15 minutes, and that the composition of the Nitroneal gas settles down to the set figure within a further 10 minutes at the most. This is of great importance for intermittent use.

* Marketed by Baker Platinum, Ltd.

Metal Supplies and Powder Metallurgy To-morrow

By H. W. Greenwood*

The rate at which high grade deposits of many metal ores are being used up gives point to methods for processing lower grade materials. Reference is made to the application of hydro-metallurgical and ion exchange methods and attention drawn to the fact that in certain processes metal powders suitable for use in powder metallurgy are produced.

THERE has been plenty of evidence in the last few years that stocks and supplies of metals are being used at a rate which calls for greater economy in usage, or newer and larger areas for future development. It is significant that metals which were once looked upon as common, and priced accordingly, are now much higher in price, and are no longer in supply beyond the everyday needs of industry. There are also rarer metals, the demand for which has increased enormously, that are now in short supply. In powder metallurgy, there is constant complaint at the high price of metal powders, and in this particular sphere high prices have most definitely stood in the way of more rapid development. Comparatively recent developments in metalliferous mining and in the extraction of minerals from their ores, and especially the separation and preparation of pure metals, offer great possibilities in the near future, not only of larger supplies of pure metals, and in particular metal powders, but also of production costs showing substantial improvements compared with present day figures. At the same time, there have been demonstrated methods of extraction that will permit of the economic development of deposits that hitherto have been considered of too low a grade for exploitation. There are developments in many mining areas, at home and abroad, in which a combination of modern methods of mining and mineral concentration with hydro-metallurgical methods of extracting and separating metal values have not only opened up many low grade deposits, of which there exist many millions of tons in almost every country, but are also capable of producing metals in powder form which combine the advantages of fine particle size and high purity. They also promise excellent recoveries at costs which compare more than satisfactorily with any other present day process.

Nickel-Copper-Cobalt Separation

One interesting example that has been described recently in the technical press[1] deals with deposits of nickel-cobalt-copper sulphides found at Lynn Lake, Manitoba. The ore as mined runs 1·223% nickel, 0·618% copper and some cobalt. The extraction process now to be outlined has been thoroughly tested, first in the laboratory, and later by increasingly larger batches, until today a new plant has been erected that can handle 235 tons of concentrates per day. The procedure is as follows. As the nickel-copper-cobalt occurs as sulphides, it is amenable to flotation and provides a 30% copper concentrate and also a nickel-cobalt concentrate with some copper. The rich copper concentrate can be smelted economically by conventional smelting methods. The mixed nickel-cobalt-copper sulphides react in an autoclave in the presence of ammonia and oxygen at comparatively low temperature and pressure (125 lb./sq. in. at 65–105° C.) and yield metal amines, hydrated iron oxide and ammonium thiosulphate. The contents of the autoclave are separated stage by stage. First the tailings are removed, then the copper as sulphide is separated off, and finally the nickel and cobalt as separate metal powders of high purity and of particle size approximately 50μ. Recoveries are 90–95% of the nickel, purity 99·95% and 50–75% of the cobalt of purity 99·6%. The residual ammonia is finally converted into ammonium sulphate and disposed of as such.

The whole process, under proper control of oxygen concentration, pressure and temperature, carries out the concentration and separation of the nickel, copper and cobalt without the necessity for any roasting or other reduction treatment of the ore. The scale of operations can be judged from the fact that ore reserves at present proven amount to some 14 million tons at Lynn Lake. With the new refinery coming into operation in January next, the all-wet process is expected to show an annual saving of 2½ million dollars compared with conventional processes. Of special interest to the powder metallurgist is the production of nickel and cobalt powders of fine particle size and high purity as an end product: also of interest is the production of a 30% copper concentrate by flotation from an ore with an average of only 0·618% copper. This is a reminder of a recent venture in North Wales, where an area not far from Llanrwst (where copper had been mined in times past) has recently been opened up, and a flotation plant installed capable of handling such quantities of material as will ensure a reasonable return.

The flotation process can handle sulphides most successfully, and might well be applied to large areas in Wales and the North of England where low grade lead ores exist, and lead-zinc ores are also to be found. The deposits are not sufficiently rich to attract the old-time type of mining, but there are many millions of tons of material containing lead and zinc values that might be well worth exploiting by modern methods. Hydro-metallurgical or leaching methods are finding favour in many areas besides Lynn Lake. In Australia, for example, they are being tried out at Mount Morgan, Queensland[2] where leaching is being used in two forms: firstly to provide a solution of copper that can be

* Powder Metallurgy Ltd.

electrolysed to produce an electrolytic copper powder; and, secondly, a leaching with ammonia and oxygen under pressure, and the chemical reduction of the copper to produce a pure metal. Here the intention is to obviate the smelting and electrolytic refining of the blister copper. If the process is successful, a saving of about £A.50. per ton is hoped for. On the two processes, with an annual output of some 6,000–7,000 tons of copper, a saving of £A.300,000 per year is thought to be possible.

Ion Exchange Processes

There are other possible methods of extracting metals, and there is much interest in the application of the processes of ionic exchange, particularly in the recovery of metals from dilute solutions.[3] It will be obvious that methods of ionic exchange can be used in concentrating metal values from mine water and from the leaching of waste or spoil heaps. It can also be used to separate mixtures of metals in the form of salts, or it may be used to purify electrolytes. Of immediate interest to the metallurgist is the use of ion-exchange methods in the recovery and separation of metals in very dilute solutions. Not only are the operating costs low, but such procedures do not normally call for very expensive plant, either as a first cost or for maintenance. A complex Canadian gold ore has yielded to the treatment, and a mixture of gold and silver, nickel, copper and zinc is adsorbed on an anion exchanger. The adsorbed copper and zinc are eluted, or removed with caustic soda, iron and nickel by hydrochloric acid and the gold and silver with acidified acetone. Australia is very interested in the recovery of silver and gold, cobalt, and nickel and zinc from cyanide solutions. In this case, the cyanide solution is passed through a column of Ambolite IRA.400, a strong base anion exchanger produced by a United States manufacturer, Rohn & Haas. All the metals are adsorbed as complex cyanides which can be eluted, or dissolved off selectively from the resin by successive treatments with different reagents as explained for the Canadian ore.

A very interesting study of the ion exchange process, and of its particular application to the recovery of gold from cyanide solutions, was made at the Chemical Research Laboratory at Teddington and the results published in an American Journal.[4] In it, the process of selective elution using specially selected reagents is fully described and illustrated by a flow sheet.

Application to Uranium Extraction

A South African application of an ion exchange process is discussed in an American journal[5] and also referred to in a South African mining journal.[6] It is the use of an ion exchange resin in the extraction of the uranium values from the South African gold ores. Here the uranium is leached from the crushed ore by sulphuric acid, and the resulting solution is then passed over the ion exchange resin, uranium being finally dissolved from the resin.

The occurrence of uranium in very low concentration in the granite domes of the Matopos was mentioned at a recent meeting of the South African Association for the Advancement of Science,[7] and it was then suggested that so low a concentration as occurred would naturally call for a technique similar to that utilised in the recovery of gold values from the Rand ores. Incidentally, it was pointed out that the sulphuric acid required for leaching out the uranium from the ore could be produced locally from pyrites found in the area.

The possibility of one or other of the methods of leaching out uranium being applied to the Cornish ores known to contain that element will naturally suggest itself. The element occurs at a number of localities in the Duchy, but rarely in large quantities. It is probably disseminated over a reasonably wide area, and in the years between 1890 and 1903 several hundred tons of uranium ore were raised with a value of nearly £20,000. Nickel and cobalt were also found, particularly in the St. Austell Consols and the South Terras Mine in the valley of the Fal. To-day it is not unlikely that quite respectable tonnages of materials that would not bear the cost of normal methods of mineral concentration and metal recovery could be handled economically. This would apply particularly to many of the low grade, but complex ores that occur over so wide an area in Cornwall. It may be well to recall the remark of the mineralogist, J. H. Collins, regarding the widespread occurrence of uranite or pitchblende in Cornwall. It occurs, he said, "in the shallow parts of almost every copper mine in the county."[8]

It is fairly obvious that at the present rate of exploitation the large scale deposits of uranium will soon be exhausted, and then it will be essential to win the element from low grade deposits such as can be found in Cornwall, South Africa, and many other areas. The same argument will apply to many other elements that to-day are increasingly used in industry and science. There is also the constant need for metals of a purity that was unknown only a short while ago. To this end, the hydro-metallurgical processes that have been outlined above are admirably suited. The fact that many of the elements commonly occur in nature as sulphides means that they are susceptible to ammonia leaching, and to recovery from solution by pressure hydrogen precipitation with a high purity end product as well as a worth-while recovery. In due course, this will mean the availability of metals in a form eminently suitable for the powder metallurgist, and at prices much less than are now necessary for powdered metals owing to the cost of powdering a comparatively pure metal.

The fact that these methods of metal extraction have not been employed hitherto is largely due to the commoner metals being available in rich deposits and so permitting of extraction by simple smelting methods. The much higher purity demanded to-day in many metals is a result of the development of the electrical and electronic industries, and to the fact that it is the physicist who has been mainly responsible for the application of very pure metals where impurities are to be reckoned in terms of a few parts/per million and not as a percentage.

It may well be that we are entering on a period when there will be large supplies of metal powders available which, contributing to an increasing output of powder metallurgical products, will encourage an even wider and more rapid application of powder metallurgy and its products in industry, at more advantageous prices and costs than are the rule to-day.

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Duplexing in the Foundry
Combination of Cupola and Electric Arc Furnace

By Francis J. Knight

Generally speaking, the cupola is a more economical means of melting iron than the electric arc furnace. In certain circumstances, however, a duplex method using both types of equipment can result in increased production of good quality castings at reduced cost.

SPECTACULAR cost reductions are claimed to have resulted from the installation of small electric furnaces working in conjunction with conventional cupolas at a progressive United States foundry. In addition, quality of production has improved greatly and wastage due to misruns, cold shuts, etc., has been sharply reduced.

Arc furnace receiving hot metal continuously from cupola in the background.

Before the installation of the electric furnaces, operatives found it difficult to raise the grey iron being melted in the cupolas to a sufficiently high temperature, and to obtain a sufficiently close control over the temperature to prevent production of inferior castings. Apart from this, the need to raise the cupola temperature to the maximum meant the consumption of large quantities of coke. Remaking spoiled castings and reclaiming cold iron adhering to the ladles by forming it into pigs for re-use meant that a good deal of the work was, in fact, being done twice over, and net production was less than it should have been.

Although the electric furnace is a very efficient heating and melting appliance, its cost of operation is generally higher than that of the conventional cupola. The case for the installation of such a furnace must, therefore, rest on its ability to bring down the cost of production, by increased efficiency, to the extent that it pays for itself.

Side view showing metal passing along trough from cupola to arc furnace.

Whilst it is often the case that the electric furnace fails to justify itself as a prime melter on this basis, its use as an adjunct to the conventional cupola for duplexing the metal, as obtains in the foundry concerned, makes it an economic proposition. The duplex process takes advantage of the lower melting costs of the cupola and uses the electric furnace only to give the improved performance necessary to produce castings of uniformly high quality. For this purpose, an electric furnace of relatively small size is sufficient, and its small additional cost is offset by the savings in other directions.

Before the installation of the Whiting hydro-arc furnaces and the mechanisation of the work processes, a team of thirty-six men was needed to charge the cupolas. This number has been slashed to four, although production has been stepped up from a little over 100 tons/day to 150 tons/day. Malleable iron is produced by the duplex process with two cupolas and two 9-ton capacity air furnaces operating on alternate days. The other four cupolas produce the grey

iron ; these also are run on alternate days and work in conjunction with the electric furnaces. The scheduled output has only been maintained by maximum mechanisation, and from picking up the raw material in the yard to completion of the product, automatic or semi-automatic machines handle every phase of the work.

The hydro-arc furnaces are of 3-ton capacity and use three 6-in. graphite electrodes which are controlled by a Rotatrol electronic system geared to hydraulic pumps which actuate the electrode arms. The method of operating the cupola and furnace together is to melt the iron first in the cupola, from which it is tapped at a temperature of 2,750° F (1505° C.). The metal is then led along a trough into the electric furnace, where the temperature is raised to 2850°F. (1565°C.). A desulphurising forehearth is built into the trough connecting the cupola to the launder on the electric furnace, which is located on the cradle tilt for the furnace, so that, although the trough is fixed, metal can be received and poured at the same time. Thus, the pouring is a one-man operation.

This arrangement gives very close temperature control at the moment of pouring, and the castings are, in consequence, of uniformly good quality. The extent to which production losses from defective runs have been reduced is clearly shown by the fact that, at this particular foundry, only about half a ton of iron is pigged each day now, compared with ten tons before the introduction of the electric furnace.

Furthermore, the coke consumption has been reduced by almost 20%, and the combination has speeded up production to the extent of producing 20% more molten metal per hour. The partly cooled metal adhering to ladles can be returned without delay to the electric furnace, which is also used to reheat any metal that loses temperature before pouring in moulding operations.

After the electric arc furnace had been in operation for some twenty months, the foundry superintendent estimated that the savings in remelting iron, reduced scrap and economy in coke consumption had more than offset the cost of the furnace. During the initial run-in period of some three months, 3,400 tons of grey iron were duplexed through the electric furnace at a cost of $1.52/ton. Successive cost reductions resulted from further experience and the cost after 20 months was around $1.30/ton: in an automobile plant having a similar set up, the figure is in the region of $1.16/ton. These figures are comprehensive and include costs of power and electrical energy, labour, materials, electrodes, maintenance, depreciation, taxes, insurance and interest.

Arc furnace used in duplexing metal in a large motor block foundry.

The combined cupola and furnace method of working has particular advantages where coke supplies are difficult or the fuel is of uneven quality. A poor load of coke no longer means that a lot of iron will have to be pigged, castings scrapped and production disorganised. The electric furnace just makes good any such deficiencies without fuss and without disturbing the foundry routine.

There is little doubt that the duplex method provides an economical means of maintaining the high, closely controlled temperature necessary to produce good quality castings.

Garrington Film

"They've Come A Long Way" is an appropriate title for the film showing the progress made by the firm of Garringtons, Ltd., which was founded by John Garrington, who started in a small way as a blacksmith near Darlaston, Staffordshire in 1837. In those days, his products included forgings for the tube trade, flanges, stirrups, spurs, harness, buckles, gun parts and rifle parts. As early as 1840, he was able to open his first factory, which was equipped with some dozen hammers, varying from 2 cwt. to 20 cwt., and anciliary equipment. Ninety per cent of his business was forging for the tube trade and this type of work continued to be the mainstay of the factory for many years. There was a falling demand for forgings in the tube trade in 1912, a period of general slump, but shortly afterwards, with the motor industry coming into its own, business began to prosper again. In 1919, Garringtons, which had become a limited company in 1912, became associated with G.K.N. and continued to grow steadily. By 1939, production facilities had increased five-fold, and have since been increased twelve times to meet the ever-growing demand of the current era. Today, Garringtons are believed to be the largest company in Europe producing forgings for the agricultural, motor transport, automobile and engineering industries. Truly, they have come a long way.

Honeywell-Brown Manchester Office

As a further step in their policy of maximum sales and service efficiency, Honeywell-Brown have established an office at 35, Byrom Street, Manchester, 3, as an addition to those already existing in London, Glasgow, Birmingham and Sheffield. The official opening took place on March 1st, and was performed by Mr. V. D. MacLachlan, Director and General Manager of the Company. The new office is under the supervision of Mr. Tom Jackman, and deals with business and enquiries from an area covered by Cumberland, Westmorland, Lancashire, Cheshire and North Wales.

The National Foundry College

New Premises Opened at Wolverhampton

WHEN the National Foundry College opened for its first session in January, 1948, it occupied part of the Wolverhampton and Staffordshire Technical College buildings. The facilities that were made available at that time were intended merely to provide a temporary solution of the accommodation problem, it being realised that further provision of both space and equipment would be necessary if the College were to fulfil the aims and aspirations of its founders. The generosity of the Joint Education Committee of the Technical College in relinquishing the use of the adjacent site, which they had acquired for the urgent development of their own institution, has resulted in the building of a new wing, within the Technical College precinct, to house the National Foundry College. The new premises, which, apart from one or two items, are fully equipped, were officially opened last month by Sir Gilbert Flemming, K.C.B. (Permanent Secretary, Ministry of Education).

The cost of the site and buildings was £90,000, with an additional £35,000 for equipment. The Minister of Education, in consultation with the Governors of the College, took the view that the development of the National College could only fulfil the objects of its founders if it engendered active interest from the foundry industry in the form of practical financial support. Accordingly, the Minister agreed to provide the balance of the £35,000, if industry would provide £10,000—the estimated cost of equipping the model foundry. In response to an appeal from the Governors, industry made available items of equipment to a value of £7,000, in addition to donations totalling a similar amount—a result that was most gratifying to the Governors, in that it indicated industry's whole-hearted and earnest acceptance of the challenge implied.

The Model Foundry

The National Foundry College is responsible for the highest technological education in the founding industry that is available in Great Britain, and it undertakes those activities that are beyond the scope of Colleges serving a single locality. It is appropriate, therefore, that its foundry is the most completely equipped of its kind in the Commonwealth, and has been laid out specifically for experimental work. Sand conditioning is carried out by means of a Royer unit and various small sand mills are also provided. For moulding, a number of industrial-size machines are available, including an electrical squeeze machine, a snap-flask machine, a pin-lift machine and a turnover machine : a large sand pit is also provided for floor moulding. Core-making equipment includes a large core blower, two cartridge-type units and a drawer-type core-drying stove.

A wide range of melting equipment has been installed, including a 12-in. diameter cupola, two lift-out-type crucible furnaces, each of 200-lb. capacity and gas-fired, and a Sklenar gas-fired furnace of the tilting type. The electric melting equipment, when installation is complete, will include a 15-lb. rocking-arc unit and a high-frequency set designed to operate a 10-lb. capacity fixed coil furnace and a 30-lb. capacity lift coil unit. Items of special interest include a centrifugal casting machine, designed to take moulding boxes or metal moulds for vertical axis casting, a small pressure die-casting machine, and a Durville table. The fettling and cleaning section is equipped with shot-blasting equipment, twin-high-speed grinding machines, portable grinding equipment, a power hacksaw, and various intricate fettling devices. A 75-ton press is available for the fracture and examination of castings.

Other Laboratories

Adjacent to the foundry on the ground floor is a laboratory completely equipped with all the standard equipment now available for sand and core testing. Notable items include a shatter test unit, a universal sand testing unit, and the standard equipment for permeability and compression testing. A range of laboratory-size mixers, mills and ovens is also installed. There is, too, a metallurgical analysis laboratory on this floor, available for routine work, and intended mainly for experimental foundry control purposes. A larger laboratory provides facilities for instruction in metallurgical analysis.

The X-ray section, which is located in the basement of the College, is equipped with a 250-kV X-ray set for the

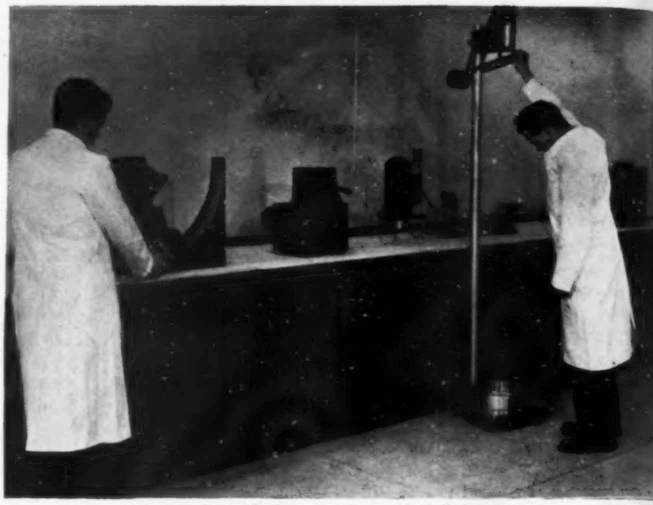
examination and radiography of castings in the various alloys. The necessary processing equipment has also been installed.

The heat-treatment laboratory on the upper ground floor contains a wide range of furnaces suitable for the heat treatment of the various cast alloys. Temperature indicating, recording and control equipment is available for use with these furnaces.

The metallography section is fully equipped for carrying out all aspects of metallographic work, the equipment including a linishing machine for rough preparation, a large number of plates for hand polishing on fine abrasive papers, and a battery of six single-type polishing wheels. There is also an automatic polishing machine.

The facilities for microscopic examination include two Vickers projection microscopes fitted with the ancillary equipment necessary for the examination of specimens in polarised light : phase contrast illumination and micro-hardness equipment is also provided. Well-equipped dark rooms are available for the production of photomicrographs. Apart from the projection instruments, a number of ordinary metallurgical bench microscopes are in use as well as binocular microscopes for low power examination.

Two spacious teaching rooms situated on the top floor of the building may be used as lecture rooms or drawing offices. They are equipped with a complete range of visual aids, including a sound film projector, film strip projector and an epidiascope. The desks used by the students are of special design, and are intended to combine the functions of drawing bench and students normal desk.



A section of the sand testing laboratory.

The College library is well equipped for the study of subjects of interest to students taking the diploma course, and a small fully-equipped section is available for the production of blue prints and the copying of documents.

Production Exhibition and Conference

"PRODUCTION FOR PLENTY" will be the theme of the Production Exhibition and Conference, sponsored by the Institution of Production Engineers and organised by the Building Trades Exhibition Ltd., to be held in the National Hall, Olympia, from 7th to 14th July, 1954.

An attempt will be made to show a comprehensive picture of the contribution of industry to the raising of our standard of living, and the Department of Scientific and Industrial Research and the British Standards Institution have stated their intention of participating in the Exhibition and Conference, whilst the British Productivity Council and other important organisations have expressed their desire to contribute to the Conference.

The Exhibition will offer facilities to Research and Trade Associations, industrial groups and perhaps some individual firms to demonstrate how their industries are contributing to a higher standard of living. As far as is practicable, the exhibits will demonstrate many different ways of improving productivity, and the Exhibition will provide an opportunity for showing designs, methods, processes and specialised equipment, which not only speed production and reduce costs, but add to the comfort, convenience and prosperity of the worker.

The Production Exhibition is not primarily intended to be a Trade Show in the usual sense of the word ; it will be complementary to other exhibitions.

The Conference will provide a platform for speakers of internal reputation to discuss the relationship between research and production in many important industrial fields. The Rt. Hon. The Earl of Halsbury, F.R.I.C., F.Inst.P., Managing Director of the National Research Development Corporation, has accepted an invitation from the Council of the Institution of Production Engineers to open the Conference by presenting the 1954 Sir Alfred Herbert Lecture.

The President of the Institution feels strongly that the presentation of a first class exhibition of this unique nature may make a very real contribution to increasing production and may also serve a vital purpose in reducing the time lag between essential research and its adaptation and use in industry. Finally, the exhibition will provide an effective means of introducing modern materials, processes and equipment to industry, and will offer a unique opportunity for senior executives of particular industries to realise the possibilities of developments in other industries.

Further information may be obtained from The Organising Secretary, Mr. S. D. Cooke, Room 11, Avenue Chambers, 4, Vernon Place, London, W.C.1 (Tel. : CHAncery 2223), or from Mr. W. F. S. Woodford, Secretary, The Institution of Production Engineers, 36, Portman Square, London, W.1 (Tel. : WELbeck 6813).

MR. A. B. LLOYD, of F. H. Lloyd & Co., Ltd., and Mr. J. D. Scarfe, a consultant production engineer, are at present in India to advise on production under the Colombo Plan Technical Co-operation Scheme. Mr. Lloyd is to survey the foundry industry to locate bottlenecks and to suggest measures to cure them, while Mr. Scarfe, who is an expert on the manufacture of machine tools, will make recommendations for rationalised production.

An Aluminium Mineral Wagon

Plating in Excellent Condition after Seven Years

ALTHOUGH it is in the transport field that the advantages of aluminium as a constructional material are most obvious, its adoption for railway rolling stock, especially goods stock, has so far been on a comparatively small scale in this country. The main reason for this is that, although in principle the desirability of reducing the tare of goods wagons is unquestioned, it is not easy in practice to prove immediate benefit from doing so. Lighter stock does not automatically permit longer trains, because it may not be possible to accommodate them on the loops and sidings of the existing system. The principal saving shown will be in reduced fuel consumption, which will become apparent only when lighter stock is used in quantity: meanwhile it is offset by the extra capital outlay.

A recent examination showed the aluminium plating to be in very good condition after carrying coal and coke for seven years: note the complete freedom from scale.

Lightness, however, is not the only asset that aluminium has to offer the railway engineer, and this is well illustrated by the history of a 21-ton mineral wagon that was experimentally plated with aluminium in 1945. At that time, when many coal producers owned their own wagons, the railway companies were charging a lower haulage rate for coal carried in large (21-ton) wagons, owing to their better gross/tare ratio. There was thus an incentive to improve the efficiency of these wagons still more in order to be able to press for a further reduction in the haulage rate.

This led the Cambrian Wagon Works, Ltd., of Maindy, Cardiff, to contemplate building a prototype all-aluminium mineral wagon, and Northern Aluminium Co., Ltd., were asked to give their recommendations as to choice of alloys and thicknesses. The builders finally decided to use aluminium for the plating only (in the same thicknesses—$\frac{3}{16}$ in. for sides and $\frac{1}{4}$ in. for floor—as the normal steel plate), retaining a steel frame and hot-driven steel rivets. Tare was then 8 tons 17 cwt. 3 qrs., compared with 10 tons 3 cwt. for all-steel construction. The unpainted wagon was put into service with a private owner, carrying coal and coke.

In the event, the demand for lighter wagons did not materialise, and after nationalisation all privately-owned stock was purchased by the Railway Executive. The prototype wagon, however, remained in service, and has on three occasions been examined to discover the behaviour of the aluminium under the extremely arduous conditions of service. From the last of these inspections, made jointly in January, 1953, by the Railway Executive, Aluminium Development Association and Aluminium Laboratories, Ltd. (on behalf of Northern Aluminium Co., Ltd.), it was evident that aluminium was an excellent material for the job on the grounds of durability alone.

Conditions from the corrosion point of view were severe. In composite structures of aluminium and steel, unless thorough protective treatment is given, there is always a possibility of galvanic interaction at bi-metallic joints in damp surroundings. In this wagon it was possible to apply paint between mating surfaces during construction, but any protective paint applied to rivet heads and other exposed surfaces would quickly have been abraded away. Various niches and crevices in the body were filled with damp coal dust, giving very unfavourable "poultice" conditions. Furthermore a large part of the wagon's life had certainly been spent in more or less polluted atmospheres.

Nevertheless, the recent examination showed the plating to be in a sound and serviceable condition after seven years' work. There was an adherent deposit on the metal which, when removed, showed that general surface attack, indicated by a whitish deposit, was very slight. It was most marked on the underside of the floor and at the lower edges of the sides, where moisture would tend to persist, and adjacent to steel members. Localised corrosion had taken place only in a few isolated instances, where dust and moisture had been trapped between steel angles and the plating, and at the side of one rivet head. The edges of the plates were still sharp-cornered and uncorroded.

Minor mechanical damage—dents, abrasions and two small punctures—was apparent (coal is normally dropped into the wagons from hoppers through a distance of six feet), though the high energy-absorbing capacity of aluminium would enable it to stand up to such impact loading rather better than steel of similar strength.

The general condition of the wagon contrasted very favourably with that of steel wagons of similar age in the same service. It is normal practice to paint the outside of steel wagons every five years, and after seven to ten years the lower part of the sides usually needs repair or replacement. It seems evident that the unpainted prototype aluminium wagon should give

years more service before needing serious repair, and its behaviour will be watched with interest.

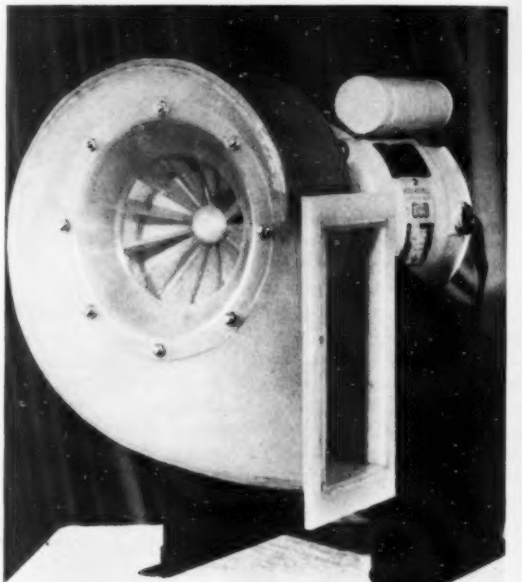
The cost of replating the sides and floor of a Railway Executive 16-ton wagon with $\frac{3}{16}$ in. and $\frac{1}{4}$ in. aluminium respectively is, at present prices, about £60; after the first normal repair period for a steel wagon has elapsed, the repair charge and revenue saved may largely offset the extra initial expenditure. The higher utilisation and longer life expected would tend to reduce the total number of wagons required and the annual building programme.

Eventually, too, the weight saving of $1\frac{1}{2}$ tons on each wagon would show its effect on fuel consumption, but meanwhile, the benefits of longer life and reduced maintenance, demonstrated by the prototype wagon, may accrue within a relatively short time.

Corrosive Fume Exhaustion Equipment

WHEREVER it is necessary to exhaust fumes of a corrosive nature, the problem of maintenance of fans and ducting arises. A new design of exhaust equipment recently introduced by the Bolton firm of Turner & Brown, Ltd., should be of considerable interest, as it is designed for such conditions of service as have been mentioned. The Company has been engaged in chemical plant fabrication for a considerable period and, as a result of experience gained in this field, has now brought out a new series of exhaust fans, coupled with a new form of ducting, which are calculated to provide many advantages.

Known as the Turbro range of centrifugal fans, they and the ducting are almost entirely constructed from a recently developed grade of rigid plastic industrial sheet (Vybak VR. 215) based upon polyvinyl chloride (P.V.C.) and supplied by Bakelite Ltd. This material has high impact and tensile strength, good dimensional stability, and exceptional resistance to chemical attack or weathering. As a result, the life of any installation fabricated from it is expected to exceed considerably that of "protected metals."



The Turbro Junior exhaust fan.

Ducting for sulphurous fumes erected at works of Thos. Burnley & Son, Ltd.

The fans range from the Turbro Junior with an extraction capacity of 300-330 cu.ft/min.—and intended for use with fume cupboards, small laboratories, etc.,—through a variety of sizes to suit individual requirements, up to a maximum displacement of 15,000 cu.ft/min. They are driven by fractional H.P. motors, and the casing, impeller and impeller shaft are made entirely from Vybak Rigid Sheet, the whole being designed so that no metallic parts are in contact with corrosive fumes. The casing itself conforms to existing principles, but is bolted to an outside frame of metal, and this arrangement allows the outlet to have no less than sixteen equi-arc positions, as well as permitting the fan to be easily coupled with existing ducting or fitted into small, enclosed areas. The impeller has twelve blades round a central boss, all made from the same material, and a hollow shaft to allow the introduction of the keyed steel shaft from the motor. All equipment is designed in strict accordance with aerodynamic principles, and a long series of tests has shown it to be virtually noiseless in operation.

The Vybak P.V.C. sheet used in this design has been specially developed to meet the need in industry for a tough constructional material which can be machined and fabricated by methods similar to those used for sheet metals, though considerably more easily. It can be sawn, drilled, routed and milled, and may also be

formed by heating above its softening point and cooling in contact with the desired contour. In addition, it can be "hot gas" welded with matching rod. It thus lends itself readily to the fabrication of all kinds of chemical plant—tanks, ducting, etc.—though, being thermoplastic, it should not be used unsupported at temperatures above 60° C. Up to this limit, however, it remains perfectly inert, with the properties already enumerated, and it may be noted that tubing and rod extruded from similar compounds are also obtainable.

Correctly used, therefore, a valuable new material has been placed in the hands of the chemical engineer and it is intended that the ducting associated with Turbro fans shall be made from it; though each can of course be used independently of the other. This, in fact, is what has happened in an installation recently completed by Turner & Brown, Ltd. in the works of Thomas Burnley & Son, Ltd., worsted spinners of Gomersal, near Cleckheaton, Yorks. Here it was necessary to replace a substantial, protected metal ducting for sulphurous fumes, which had collapsed through corrosion, and Vybak sheet, VR.215, $\frac{1}{4}$in. thick, was chosen for the job because of both its superior properties for this purpose and the comparative ease with which it could be installed in a fairly difficult position. Sections were largely pre-fabricated, leaving as little work as possible to be done on site, and the result, as the illustration shows, is a first-class exhaust unit which, with the polythene piping also to be seen, marks another important extension to the field of plastic application.

New Aluminium Casting Alloy Available

THE high strength aluminium alloy known as Frontier 40-E is now available for castings production in this country. British patent rights covering the manufacture of castings in this alloy are held by the Frontier Bronze Corporation, Niagara Falls, U.S.A. Final details of an exclusive licence have now been agreed between Mr. E. H. Holzworth, President of the Frontier Bronze Corporation, and Mr. John Vickers, Managing Director of Daralum Castings, Ltd., Darlington, whereby the exclusive rights covering the manufacture and use of the alloy in Great Britain have been granted to Daralum Castings, Ltd. Arrangements have been made for the manufacture of the ingot by John E. Moore, Ltd., of Yeadon, Yorks, and it is the intention to grant sub-licences to approved foundries in due course.

Alloy 40-E is the result of considerable research and development carried out by Frontier Bronze since the alloy was introduced in 1944. Its major constituents are

Zinc	4·74—5·75%
Magnesium	0·40—0·60%
Chromium	0·40—0·60%
Titanium	0·15—0·25%

with very narrow limits placed on all the impurities present.

The outstanding feature of this alloy is its property of age hardening at room temperature to give minimum routine mechanical properties of

Yield Stress	13 tons/sq. in.
Ultimate Tensile Stress	16 tons/sq. in.
Elongation	5%
Brinell Hardness (500/10)	75

An initial minimum natural ageing period of 21 days is necessary, although a short period of artificial ageing at 180° C. may be substituted. A test carried out over a period of 8 years has shown that the alloy retains remarkable stability, and it therefore shows distinct advantages over the common non-heat treated casting alloys, and could replace most of the heat treated alloys for specific applications. Its natural ageing ability renders the alloy suitable for welding and brazing, as castings re-age and therefore regain their mechanical properties after the heating applied during these processes.

Because of the absence of copper and other detrimental constituents, 40-E has excellent corrosion and stress corrosion resistances, which have been shown to be equal to that of the Al-Si-Mg alloys. Its machinability is superior to that of most other aluminium casting alloys.

The foundry characteristics of the alloy are about equal to those of the Al-Cu class of alloy, and experience already gained in this country indicates that no great experience is required to produce satisfactory sand castings in most common subjects. Of particular interest is the possibility of producing high mechanical properties with pressure die castings of the less complex type, without the risk of blistering often experienced when heat treating such castings. This experience is confirmed by work recently reported from France on this alloy.*

Because of its relatively high strength and good shock resistance, the alloy has been in use for some years in the U.S.A. for the manufacture of services castings, and for castings in a wide variety of industrial applications. Mining, oil refinery and ventilating equipment; road vehicle parts (e.g., rear axle casings) rail jacks and hand tools are a few of the spheres where castings in 40-E are now firmly established in America.

The alloy is covered by the following American specifications :—

U.S. Army-Navy Air Corps...	AN-A-17
U.S. Navy, Bureau of Aeronautics	AN-A-17
U.S. Navy, Bureau of Ships..	16A1, Class 1 (Int.)
A.S.T.M.	B-26-46T-ZG41
A.F.A.	B-81
S.A.E.	310
U.S. Army Ordnance	AXX-1348

and by British Letters Patent No. 627,968.

* *Light Metals*, 1954, January.

G.W.B. Control Gear

G.W.B. FURNACES, LTD. of Dudley, Worcs., manufacturers of electric heating and melting furnaces, and electrode boilers and steam raisers, announce their entry into the field of low tension control gear. They have acquired the sole licence to supply and manufacture, for the British Commonwealth, all control gear developed by the firm of Officine Meccaniche Riunite in Milan. O.M.R. have achieved a high reputation on the Continent with installations supplied to rubber firms, steelworks, chemical concerns and machine tool makers resulting in a phenomenal increase in production from 1947 to 1953. G.W.B. now supply complete panels ready wired and 'tailor made' to specification, also loose contactors, if required, for all purposes. Supplied in a standard range from 10 to 1,400 amp A.C. or D.C., the contactors incorporate a number of refinements.


HANNA

NEWS AND ANNOUNCEMENTS

Corrosion Summer School

A SUMMER School on "The Fundamentals of Corrosion and its Prevention" will be held in the Metallurgy Department of the Battersea Polytechnic from July 20th to July 23rd, 1954. The morning sessions will be devoted to lectures by S. C. Britton, M.A., T. P. Hoar, M.A., Ph.D., F.I.M., F.R.I.C., and L. L. Shreir, Ph.D., F.I.M., F.R.I.C., and in the afternoons there will be visits, laboratory demonstrations and discussions. One or two evenings will be devoted to films of corrosion interest and one to laboratory demonstrations.

The eight lectures to be delivered are, in order of presentation: "Electrochemical Principles of Corrosion" (L. L. Shreir); "Immersed Corrosion" (L. L. Shreir); "Dry Corrosion" (T. P. Hoar); "Atmospheric Corrosion" (S. C. Britton); "Underground Corrosion" (T. P. Hoar); "Inhibitors" (T. P. Hoar); "Metal Coatings" (S. C. Britton); and "Non-Metallic Coatings" (S. C. Britton). It is desirable that intending students should have attained Intermediate B.Sc. standard in Chemistry and Physics.

The fee for the course is £2. 2s. 0d, and accommodation will be available in the Polytechnic Hostels from the evening of Monday, July 19th to the morning of Saturday, July 24th, the inclusive fee for residence and main meals being £5. 5s. 0d. Applications for admission to the Summer School and for Hostel Accommodation should be made to the Secretary, Battersea Polytechnic, Battersea Park Road, London, S.W.11.

Metal Finishing Conference

AN interesting programme of technical sessions has been drawn up for the Fourth International Conference on Electrodeposition and Metal Finishing which is to held in London from April 20th to 24th. Papers will be presented by leading authorities in Europe and the United States. At each session up to half-a-dozen related papers will be discussed, the topics concerned including Anodic Processes; Fundamental Aspects; Chromium and Tin Coatings; Nickel Plating; American Electroplating Practice; Organic Finishing; Electrodeposition; and the Future.

United Steel Cambridge Scholarship

THE UNITED STEEL COMPANIES LIMITED announce that they have endowed a University Entrance Scholarship, tenable at St. John's College, Cambridge, which will be open to candidates who intend to study Physical or Mechanical Sciences at the College. The Scholarship will be offered annually at the open examination for Entrance Scholarships and Exhibitions of St. John's College, and the emolument will be £100 a year; but the College will be entitled to augment this to bring it up to a total value of £150. The emoluments will be paid without regard to a scholar's financial circumstances.

The award and administration of the Scholarship will be left entirely in the hands of the College with discretion to make modifications to the arrangements in the future in order to preserve the purposes for which the Scholarship is founded. The Company hopes that the scholars may frequently have the intention of entering industry, and be of a type likely to rise to positions of responsibility therein, and it has been suggested that where the intellectual qualifications of candidates are approximately equal, weight be given to personal qualities and background which may be deemed to fit them to become senior executives in industry.

No stipulation is made as to the future career of the scholars, although the Company hopes to make contact with the holders of its Scholarship and that for a proportion of them there may emerge a common wish that they should make their careers with the Company.

Maintenance of Automatic Welding Equipment

FUSARC, LTD., are now holding regular courses at their works on the maintenance of automatic welding machines. The courses have been designed for maintenance electricians or personnel in a similar category, and are open to users or potential users of Unionmelt and Fusarc automatic welding equipment.

Lectures on the processes and methods of arc control, demonstrations of machines and generator groups, and demonstrations of faults and fault location are given, in addition to practical work in the stripping down and repairing of standard machines, re-erection and the carrying out of test routines. Time is also devoted to examination and explanation of the wiring diagrams of machines where they are used in connection with special jigs and manipulators. The courses on Unionmelt and Fusarc equipment are run separately, and under normal circumstances a week is devoted to each so that personnel may attend either or both as required by the equipment at the customer's works. Further details and syllabus can be obtained on application.

Anglo-American Instrument Co-operation

ELLIOTT BROTHERS (London), Ltd., the industrial instrument engineers, have concluded a licence agreement with the Bristol Company of Waterbury, Connecticut, U.S.A., and have acquired the business of Bristol's Instrument Company of Weymouth. Broadly speaking, the Bristol range of instruments is complementary to that of Elliott Brothers, and the combination of the two will provide a source of comprehensive and well-balanced instrumentation.

Factory Equipment Exhibition

OVER 100 exhibitors from all parts of Great Britain have booked space for the second National Factory Equipment Exhibition, to be held at the Horticultural Halls, Vincent Square and Greycoat Street, Westminster, London, from March 22nd–26th, 1954.

This exhibition is the only one of its kind which brings mechanical handling devices, packaging, storage, safety and welfare, as well as works office equipment, all under one roof at the same time. There will be fork lift trucks, power-operated jacks; machines for packing, tying and labelling cartons and boxes, new types of storage racks for factories, a display of office equipment of all kinds, together with office systems to simplify the most complex of filing operations, in addition to internal call systems and a variety of canteen equipment. Several items of

equipment in each range will be completely new, and will not previously have been shown at any trade exhibition.

Lord Rochdale, the newly-elected President of the National Union of Manufacturers and a well-known industrialist, will open the exhibition. The Duke of Edinburgh, who visited the first National Factory Equipment Exhibition last year, has consented to become its patron for 1954.

Instrumentation in Industrial Hygiene

A Symposium on Instrumentation in Industrial Hygiene, organised jointly by the Institute of Industrial Health and the School of Public Health of the University of Michigan, will be held at the University on May 24th–27th, 1954. It is hoped that as a result of the meeting, both makers and users of instruments will be more fully informed as to what is available and what is needed in the field. Further information can be obtained from: Director, Continued Education, School of Public Health, University of Michigan, Ann Arbor, Michigan, U.S.A.

European Oil and Natural Gas

The Oil Committee of the Organisation for European Economic Co-operation has undertaken a study on the search for, and exploitation of, crude oil and natural gas in Member countries, a problem of great importance to the economy of Europe. The main points to be studied are: geological information, mining and fiscal regulations, current operations and operating resources in Europe. This is a new activity for the Oil Committee, which up to now has been chiefly concerned with co-ordinating the development of refinery capacity and making periodical surveys of trends in the production and consumption of petroleum products.

The study will be of great assistance to governments desirous of encouraging the search for, and exploitation of crude oil and natural gas in their own territories, since it will provide them with detailed information on the results obtained in other countries. It should also give practical guidance to private investors in oil prospection in Europe.

Dollar Earning Plating Process

Arrangements have been completed by Silvercrown, Ltd., of 178, Goswell Road, London, E.C.1, for their Nickelex and Bright Nickelex processes to be used by American industry on a royalty basis. The exclusive distributors in the U.S.A. will be Metal & Thermit Corporation, of New York. In addition to Great Britain and the Commonwealth, the Nickelex and Bright Nickelex processes are already in operation in most European countries.

Personal News

At a symposium on "The Non-Ferrous Metal Industry in India," organised under the auspices of the National Metallurgical Laboratory (Council of Scientific and Industrial Research) of India, Mr. F. C. Goldsmith, resident technical representative of Foundry Services (Overseas), Ltd., read a paper on "The Chemical Treatment of Molten Non-Ferrous Metals."

Sir Rex Hodges, whose retirement from the position of General Manager and Secretary of the Mersey Docks and Harbour Board has been announced to take place in March, is joining the Board of British Insulated Callender's Cables, Ltd., as from 31st March, 1954.

Mr. K. E. Jermy has left Central Research Establishment II of the National Coal Board to take up an appointment with the Zinc Development Association in Oxford.

The Telegraph Construction and Maintenance Co., Ltd., announce that Mr. J. N. Dean has been appointed Deputy Chairman of the Company. The executive duties of the Board will no longer be vested in a Managing Director, but will be carried out by a Managing Board, of which Mr. Dean, as Chief Executive, will be Chairman. Mr. C. L. G. Fairfield, who joined the Company in April last as Manager of the Overseas Division, has now been appointed General Sales Manager covering cables, plastics and engineering products. Mr. E. H. Gosling, previously Home Sales Manager of Telcon's Cables Division, has been appointed Home Sales Manager for these products.

In accordance with developments envisaged at the time of the formation of Telcon Telecommunications, Ltd., owned jointly by Mullard, Ltd., and The Telegraph Construction and Maintenance Co., Ltd., Mr. J. Innes, C.B., a Director of the latter Company, has relinquished the Managing Directorship and his Directorship of Telcon Telecommunications, Ltd., but will continue to act as Consultant to the Board. Mr. C. L. G. Fairfield, Telcon's General Sales Manager, has been appointed a Director as one of the three Telcon representatives on the Board. Mr. W. Sampson has been appointed Executive Director and will take over Mr. Innes' managerial duties.

Mr. L. Pardoe has been made an additional Director of Ductile Steels, Ltd.

The Senate of the University of Sheffield has appointed Dr. A. R. Entwisle, a graduate of the University of Cambridge, who for some time past has been engaged in metallurgical research in Sheffield, to be the first United Steel Companies' Research Fellow in Metallurgy. Dr. Entwisle will study the effect of interstitial elements on the formation of martensite.

The Steel, Peech and Tozer Branch of The United Steel Companies, Limited, announces that Mr. P. Beynon will be appointed Manager of the newly formed Work Study Department. Although some months may elapse before this new service begins to operate, Mr. Beynon will relinquish his position as Spring Shop Manager on 1st March, 1954, in order to be able to devote his full time to forming the new Department. Mr. E. Houghton (at present Assistant Spring Shop Manager) will succeed Mr. Beynon as Spring Shop Manager on 1st March, 1954.

Mr. D. D. Hawley, M.C., has been appointed to the Board of Hadfields, Ltd., as Sales Director. Mr. Hawley joined the Company in 1919, was appointed Sales Manager in 1946 and became a Local Director two years later. He represents the Company on various Trade Associations and is a member of the Executive Council of the British Steel Founders' Association.

Newman Industries, Ltd., announce the appointment of Mr. L. M. Reay, M.B.E., as London Sales Manager for their Electric Motor Division. Mr. Reay has been with the Company for five years as Sales Engineer in the London area.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Radioactive Isotope Containers

THE Newton Victor range of radioactive isotope containers embodies several new features concerned with the safety of the operator, and of all who have occasion to move or handle such devices. The containers are so designed that the intensity of radiation from the radioactive source is reduced, by built-in protective screening, below the tolerance dose at the surface of the container: i.e., it is perfectly safe to touch or handle the container for any period up to 40 hours per week. Further, the source may be attached with complete safety either to a rigid rod or flexible cable, and remain so attached both for radiography of individual specimens and for panoramic work. The need to extract the source from the container and to carry it to the radiographic position—exposing the operator to the risk of harmful radiation in the process—is thus entirely eliminated.

A special remote control device can be provided if required, by means of which—and from a safe distance—the source is moved in and out of the container through a number of lengths of light alloy tubing attached to the container-front. The source is rigidly mounted on a flexible cable running in the tubing, and operation of a control handle, remote from the container, brings the isotope safely to the pre-determined exposure position for a panoramic series of radiographs, or for the examination of a complete circumferential weld in a pressure vessel. Alternatively, the tubing may extend throughout the length of the pressure vessel and the isotope move from joint to joint with the aid of a distance-measuring device incorporated in the control handle. At the conclusion of each exposure, the source can be returned to the container by turning the handle, so that every type of examination can be carried out without the operator being exposed at any time to radiation intensities above the tolerance dose rate.

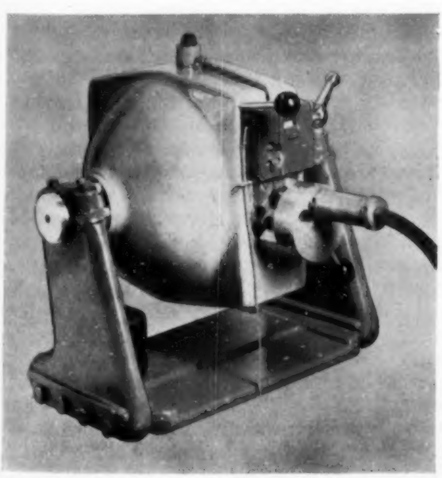
Each Newton Victor container is designed to house two independent radioactive sources in a three-position rotating drum. One source—for example, Cobalt 60 with a strength of 5 curies—may be attached to the remote control device, and with the drum rotated into the appropriate position is ready for operation. The other source—perhaps iridium 192—with a much shorter "safe distance" is attached when required to a handling rod, and is ready for use when the drum is turned appropriately. The second source, however, may also be attached, if desired, to a second remote control device. When the drum is in the locked position, both sources are completely shielded, and it is impossible for a person without the key either to obtain access to the isotope or to be exposed accidentally to harmful radiation.

Access by the operator to the position the isotope is to occupy for any particular radiograph is not in any way necessary. As long as the location can be reached with the end of the light alloy tubing (10, 20, 30 ft. or more) the exposure can be successfully made. Radiographs may even be taken of the hulls of ships afloat, or of vessels filled with liquid, providing the latter does not attack the tubing. Similarly, the radiation source may quite easily be positioned up to 40 ft. inside a welded pipe for the examination of a suspected faulty joint.

Newton Victor, Ltd., 132, Long Acre, London, W.C.2.

Self-Cleaning Air Filter

THE first all-metal viscous-oil-wetted type of air filter with removable cells was introduced to the British market by The Visco Engineering Co., Ltd., in 1921. This was followed by a patent rotating self-cleaning filter in 1932, but under more arduous dust conditions, such as obtain in a steelworks for example, it was found that the heavy accumulation of dust on the filter cells could not be effectively removed by passing through the oil tanks at the base of each filter section, and to cope with these conditions an oilspray type was developed. In the new Visco Reciprojet Self-Cleaning Filter, the



The radioactive isotope container seen on the left, contains two sources, one or both of which can be attached to a remote control device seen in action on the right.

cleaning of the cells is carried out automatically, the operation being controlled by a time switch, so as to ensure that each cell is thoroughly cleaned at regular and frequent intervals. By the use of a double column of filter cells, higher filtration efficiency is obtained and the possibility of oil carry-over is eliminated.

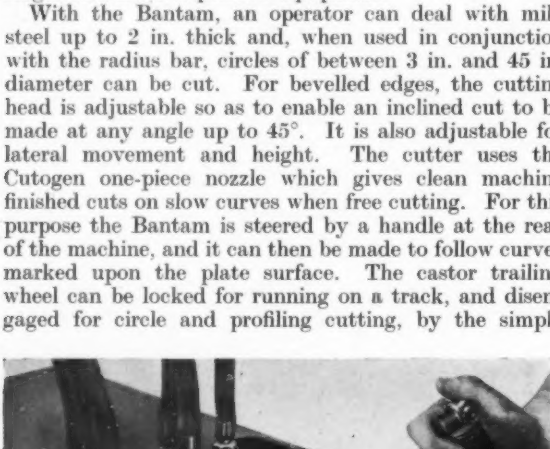
The Reciprojet consists of one or more sections of various heights to suit the required capacities, each section comprising a mild steel frame having two columns of filter cells supported in carrier plates attached to two endless chains. At the base of each section is an oil tank of ample capacity, having a large-sized access door. At predetermined times an electrically-operated time switch starts up the fractional horse power motor which drives the filter columns and an oil pump motor. This brings the dirtiest cell in each section into the cleaning position, where it is subjected to the scouring action of a number of full bore oil jets which move backwards and forwards across the width of the cell. The dirty cell is initially tilted to allow the oil jets to wash the dirt forward and downwards through the cell plates, and as the cell continues to move, the oil jets effectively scour the front or dirty face.

Visco Engineering Co., Ltd., Stafford Road, Croydon.

The Bantam Gas-Cutting Machine

THE Bantam, for straight line and circle cutting is the latest of The British Oxygen Company's cutting machines and is also the lightest, weighing only $22\frac{3}{4}$ lb., including the cutter. Designed as a maid of all work, it is, although small, one of the sturdiest machines of its kind ever produced and has many of the advantages of much larger and more expensive equipment.

With the Bantam, an operator can deal with mild steel up to 2 in. thick and, when used in conjunction with the radius bar, circles of between 3 in. and 45 in. diameter can be cut. For bevelled edges, the cutting head is adjustable so as to enable an inclined cut to be made at any angle up to 45°. It is also adjustable for lateral movement and height. The cutter uses the Cutogen one-piece nozzle which gives clean machine finished cuts on slow curves when free cutting. For this purpose the Bantam is steered by a handle at the rear of the machine, and it can then be made to follow curves marked upon the plate surface. The castor trailing wheel can be locked for running on a track, and disengaged for circle and profiling cutting, by the simple adjustment of a locating screw. A 3 ft. light alloy track is provided with the machine, and further lengths can be bought separately for extending it.



There is a reversing switch for straight cutting when mounted on the track, and to enable the nozzle to be quickly lined up over the work a cross traverse arm is fitted with a quick acting locking lever, a refinement not usually found on a machine of this kind. Performance of course depends on several factors but the examples tabulated give a picture of the machine's capabilities.

All steel parts are oxidised to prevent rusting: the light alloy parts are anodised and the attachments chromium plated. These features together with its attractive range of applications should make the Bantam a very popular addition to British Oxygen's cutting machine family.

TYPICAL PERFORMANCE FIGURES FOR BANTAM CUTTER

	Nozzle Size in.	Plate Thickness in.	Cutting Rate ft./hr.
Straight Line Cutting	$\frac{1}{32}$ $\frac{3}{64}$ $\frac{1}{16}$	$\frac{1}{8}$ $\frac{1}{2}$ 2	130 80 40
Bevel Cutting	$\frac{1}{32}$ $\frac{1}{16}$ $\frac{1}{16}$	$\frac{1}{8}$ $\frac{1}{2}$ 2	66 42 30

The British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

Radiograph Viewing Lantern

ILFORD LTD., have introduced a new viewing lantern for industrial X-ray films, which has been specially designed to enable much higher densities to be viewed than has been possible before, densities in the region of 4 being easily appreciated.

The chassis comprises two parts built of heavy gauge sheet metal. The base supports the sodium lamp in its vacuum jacket, and the jacket is surrounded by a rotatable baffle of semi-circular section, running on rollers and operated by a hand grip on the right hand side of the outer casing. This baffle enables the direct light to be cut off so that films of lower density can be viewed. Air vents are provided in the base, which has four feet, two of which are adjustable for levelling purposes. The casing has a viewing panel inclined at about 45° to the horizontal for films up to 15 in. ×6 in. in size. The panel, which also acts as a diffuser, is of opal Perspex and is held top and bottom in slots. Hinged to the casing above the panel is a double hinged mask, whereby the viewing area can be masked down for use with films either 15 in. ×4 in. or 15 in. ×2 in. Behind the panel, sliding horizontally, are two adjustable masks running in channels. These are operated by draw-rods from each side, so that the viewing area can be cut down to a narrow slot 6 in. long. Below the masks, and about 1 in. from the viewing panel, is a sheet of $\frac{1}{4}$ in. Calorex heat-absorbing glass. Films are retained on the viewing panel by means of a groove at the lower edge.

A 140-watt sodium vapour lamp is used, and the level of illumination is very high—1,250-foot lamberts at the viewing panel. Due to the efficiency of the lamp and of the ventilation system, the temperature of the viewing panel reaches only 90°–100° F. under average conditions. The lamp is operated from a specially designed ballast giving an initial voltage of approximately 500, dropping to about 200 after switching on.

Ilford Ltd., 134, St. Alban Road, Watford, Herts.

CURRENT LITERATURE

Book Notices

HANDBOOK ON DIE CASTINGS FOR THE USE OF SERVICE DESIGNERS AND INSPECTORS

Sponsored by the Adv:sory Committee (Die Castings) Ministry of Supply, and compiled by Mr. F. D. Penney of the Ministry's Armament Design Establishment. London, 1953. Her Majesty's Stationery Office. 6s.

THIS handbook is intended primarily to assist the designer to appreciate the advantages and limitations of die casting processes, to assess the suitability of a particular component for production as a pressure or gravity casting, and to choose the best materials available, guidance is also given in designing the component in order that full advantage may be taken of the potentialities of the process and the materials chosen.

It will also be of value to those concerned with the production and inspection of die castings, both for the Services and general usage, as will be seen by the following chapter headings: (1) General Considerations of Design, (2) Pressure Die Casting, (3) Dies for Pressure Die Casting, (4) Gravity Die Casting, (5) Alloys for Die Casting, (6) The Design of Die Castings, and (7) The Service Inspection of Die Castings.

The handbook is fully illustrated with photographs and line drawings and also contains tables giving data on the composition and physical and mechanical properties of die casting alloys, on limiting sizes, and on recommended tolerances.

DENSENING AND CHILLING IN FOUNDRY WORK

By E. Longden, M.I.Mech.E., 178 pp., 110 illustrations. London, 1954, Charles Griffin & Co., Ltd. 28s. (by post 29s.).

THE production of sound castings has been an everyday problem to foundrymen since castings were first produced—and still is. So many factors influence the quality of castings that considerable initiative and skill are necessary to meet the needs of modern engineering practice, and experience plays a very important part. All the skill of the moulder, the ability and experience of the metallurgist in preparing the alloy, and of the furnaceman in supplying it at the right temperature, will not necessarily make a sound casting, although the combination materially reduces the percentage of wasters. Great progress in the production of high quality castings has been made in recent years, but, as yet, there is no scientific formula upon which the founder can work to eliminate loss.

In this book, the author provides what is, undoubtedly, a major contribution to the solution of problems associated with the production of sound castings. Their manufacture depends upon many control factors, the chief of which are: (*a*) choice and manipulation of a suitable metal composition to meet specification requirements; (*b*) production of a mould with adequate provision for compensating liquid shrinkage, and designed for the minimum of hindered solid contraction; and (*c*) selection of mould materials with the most effective thermal conductivity properties, and resistance to elevated temperature, fluid pressure, and localised or general failure of the mould walls. These factors provide the subject matter for this treatise, with emphasis on the influence of various mould materials on the apparent structural soundness and density of ferrous and non-ferrous castings, particularly, the use of denseners or chills to effect control.

The fact that practically all metals shrink and contract in cooling from the molten condition to room temperature is largely responsible for the difficulties encountered in making sound castings, especially as different metals and alloys have different coefficients of expansion and different rates of freezing. The more rapidly a metal solidifies and cools to below its particular critical temperature ranges, the greater the soundness and density of the metal or alloy. With designs of castings that are reasonably regular in their sectional thicknesses, shrinkage and contraction defects are more easily overcome, but there are many designs which carry both heavy and light sections, in the manufacture of which densening and chilling are the only satisfactory means of increasing the cooling rate of the thicker sections and thus increasing their density.

To the reviewer's knowledge, the many books on foundry practice either gently skim the subject discussed so intimately by Mr. Longden, or conveniently miss it out altogether. It is very refreshing, therefore, that the author, with his wide theoretical and practical knowledge and high standing in the foundry industry, should give foundrymen, both present and future, the benefit of his long experience in dealing with difficult castings.

The general influences which determine the soundness, density, and chilling properties of cast metals and alloys are reviewed from a metallurgical point of view, and the results of tests on the influence of elements on structure are summarised. The systems of mould construction which have the most potent influence on the degree of soundness and density are considered in relation to heat conductivity, and experiments are discussed showing the influence of mould materials on cast iron. The author's observations on the use of denseners are thought-provoking, and it is noteworthy that he includes those denseners that become part of the section of the casting. Detailed information is given of many types of denseners and their particular use. In a chapter dealing with the treatment of castings, a roll-grinding machine bed in cast iron is used as an extreme example for study. It is 30 ft. long and may vary in width with two to four slideways, the latter being 2½ to 3½ times the main sectional thickness of the casting. Even with the aid of denseners the cooling curves of this casting, taken over a period of 340 hours, show conflicting stresses. On the question of camber, which so frequently arises when foundrymen gather, the master chart on page 38 should prove invaluable. Many chapters are given to practical examples showing the variety of uses for the many types of denseners. Of particular interest amongst these is the making of a 19-ton gun tube boring bar in cast iron—22 in. diameter and 47 ft. long. Much detailed information is included on chilled castings, such as car and waggon wheels, high-duty rolls and chilled rolls, and a further chapter on iron castings deals with permanent and semi-permanent moulds. Several examples of the manufacture of steel castings are described, and the application of denseners to the manufacture of non-ferrous castings is discussed and examples detailed,

including the use of permanent moulds. The use of centrifugal action to produce dense castings is also discussed, and both vertical and horizontal machines for spun castings are described; in this latter chapter is tabulated a comparison of casting densities from green, dry and spun moulds for a variety of non-ferrous alloys. The final chapter is devoted to the reproduction of some typical photomicrographs of various metals and alloys.

This is a book on a subject that is rarely discussed in technical literature: the author has studied the densening and chilling of castings for a great number of years and has adopted the practice to solve problems in the manufacture of difficult castings when no other technique offered a solution; the information given therefore, is, authoritative and reliable and is essentially practical. It is the type of book which should be carefully studied by foundrymen, particularly those in charge who are looking for new ideas and guidance in improving the quality of castings produced. The reviewer has no hesitation in saying that, of the many books so far published on castings production, this book is outstanding. C.A.O.

Trade Publications

We have received from Hopkin and Williams Ltd., Chadwell Heath, Essex, three monographs, written by members of the staff of the Hopkin and Williams' Analytical Laboratories, dealing with the use for analytical purposes of certain organic reagents. The purpose of each booklet is to provide a complete review of the analytical uses of the reagent concerned, and to select the most satisfactory procedures for what appear to be the more important applications. Monograph No. 11 (1953) deals with a reagent for boron—1 : 1′-dianthrimide; No. 12 (1953) with *bis*-cyclohexanone oxalyldihydrazone for copper; and No. 13 (1953) with nitron (1 : 4-diphenyl-3 : 5-endanilo-4 : 5-dihydro-1 : 2 : 4-triazole) for nitrate, and also for tungsten, perchlorate and rhenium.

Beryllium Smelting Co. Ltd., 36/38, Southampton Street, London, W.C.2, have recently issued two new publications entitled "Berylco Product Directory" and "Applications Unlimited." The former details the master alloys, wrought beryllium, copper products, casting ingots, castings, forgings, and a number of beryllium alloys and compounds, made by The Beryllium Corporation, U.S.A. for whom the Company acts as sales representative in the United Kingdom. "Applications Unlimited" is described on the cover as "The Success Story of Beryllium Copper" and, as may be expected details numerous uses for which the material is ideally suited.

Woodall-Duckham came into being in 1903 when the original patent in connection with the Woodall-Duckham Continuous Vertical Retort was taken out by Lieut. Col. H. W. Woodall, C.I.E., and Arthur Duckham (later Sir Arthur Duckham, G.B.E., K.C.B.). 1953 was, therefore, the Jubilee of the Woodall-Duckham Company, and to mark the occasion a handsome, illustrated brochure of the Company's activities was issued. After a brief historical introduction, in which reference is made to the firm's entry into the coke oven field in 1923, the brochure presents a pictorial representation of current work, showing within its limitations the extent and magnitude of the Company's operations at the present time. The brochure is thus a tribute to those pioneers who founded and developed the organisation, since no greater compliment can be paid to them than to present a picture of the Company at work to-day. The three main sections—Continuous Vertical Retorts, Coke Ovens and Intermittent Vertical Chambers— are illustrated by coloured prints of typical installations, prefaced in each case by a brief note describing how the different systems work.

In addition to the usual requirements of adequate mechanical strength, springs must often be used in conditions which add further problems in specifying the material which will give the required properties. Such requirements may include resistance to corrosion to minimize failure due to corrosion-fatigue, or resistance to high-temperature conditions. Sometimes a special characteristic is required such as amagnetism at temperatures in the sub-zero range, or low or high electrical or thermal conductivities; sometimes a combination of characteristics is required, as for instance in springs for accurate instruments where low thermal expansion and zero thermo-elastic coefficients are desirable. Such properties and characteristics are available in the wide range of high-nickel alloys and a recent publication "Nickel Alloy Spring Materials," issued by Henry Wiggin & Co. Ltd., presents in convenient form, data to assist the designer to make the correct selection of materials. First published two years ago, this revised edition now contains data on Nimonic 90, an alloy which is rapidly winning acceptance for springs operating at high temperatures.

We have received from Funditor, Ltd., 3, Woodbridge Street, London, E.C.1, a pamphlet describing their industrial electric furnaces, which are suitable for melting lead, tin, solder, bearing metals and zinc alloys: in fact all soft metals requiring temperatures up to 600° C. They include bale-out furnaces; hooded furnaces with a manually controlled pouring valve for drawing dross-free metal from the base of the crucible; tilting furnaces; solder and tinning baths; and die-casting machine metal pots. The first three of these are available in a range of sizes up to one ton.

Books Received

"Fundamentals of the Working of Metals." By G. Sachs. 158 pp. London, 1954. Pergamon Press, Ltd. 30s. net.

"Non-Ferrous Foundry Metallurgy." The Science of Melting and Casting Non-Ferrous Metals and Alloys. Edited by A. J. Murphy, M.Sc., F.I.M. 497 pp. including numerous illustrations and index. London, 1954. Pergamon Press, Ltd. 70s. net.

"Twinning and Diffusionless Transformations in Metals." By E. O. Hall, M.Sc.(N.Z.), Ph.D.(Cantab.). 181 pp. including author and subject indexes. London, 1954. Butterworths Scientific Publications. 30s. net. By post 10d. extra.

"Analysis of Deformation." Vol. 1—Mathematical Theory. By Keith Swainger, Ph.D.(Eng.), London. 285 pp. including index. London, 1954. Chapman and Hall, Ltd. 63s. net.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC

INSTRUMENTS AND MATERIALS

MARCH, 1954 Vol. XLIX, No. 293

The Application of the Complexones in Metallurgical Analysis—II

By E. G. Brown, A.M.C.T., F.R.I.C.

Since 1945, considerable attention has been given, particularly by Czechoslovak workers, to the application of the complexones in analytical chemistry, and good progress has been made in their use in certain fields, notably water analysis. In this survey the author refers to specific proposals for the use of complexones in metallurgical analysis, this second part dealing with the non-ferrous field.

(*Continued from the February issue.*)

NON-FERROUS APPLICATIONS

Beryllium

An example of the use of the complexones as masking reagents is detailed by Luke and Campbell[24] in the determination of beryllium in beryllium-copper alloys. Ethylenediamine tetra-acetic acid has been recommended by Pribil and Kurcharsky[25] as a complexing agent in the separation of beryllium as the hydroxide, in the presence of such elements as aluminium, manganese, chromium, lead, bismuth, copper, cadmium, zinc, cobalt, nickel and iron. This was applied by the American workers for the photometric determination of beryllium in 2% beryllium-copper alloys, using an aluminon method. No preliminary separation of beryllium is required and, in addition to the above elements, there is no interference from moderate quantities of zirconium and titanium. Under the conditions specified, not more than 10 mg. of copper can be tolerated.

A similar procedure was reported earlier by Meek and Banks,[26] who determined beryllium in aluminium by sulphosalicylic acid spectrophotometrically. There again, interference by the aluminium-sulphosalicylic complex was obviated by complexing the bulk of the aluminium with Complexone II. Copper and iron must not be present in more than trace amounts.

In their original papers, Pribil and Kurcharsky[25] applied the selective precipitation of beryllium hydroxide to the analysis of beryllium alloys. 1·0–1·5 g. of metal turnings were dissolved in nitric acid, and copper determined electrolytically. After the removal of copper, ammonium hydroxide was added to permanent turbidity, and the turbidity then cleared by a few drops of hydrochloric acid. After the addition of 0·5M complexone (diammonium salt), the beryllium was precipitated with 15 ml. 14% ammonium hydroxide in the cold. The hydroxide was filtered off, washed with hot ammonium nitrate solution, strongly ignited and weighed as BeO. The results shown in Table VII are quoted by Pribil and Kurcharsky.

TABLE VII.—DETERMINATION OF BERYLLIUM IN BERYLLIUM-COPPER

Material	Determination No.	Beryllium Found—%
Sample containing 1·98% Be and 0·19% Co ..	1 2	2·00 1·94
Sample: Belzer Conus Crucible Tongs (special alloy)	1 2	2·17 2·19

Bismuth

Pribil and his collaborators have described two methods for the determination of bismuth in lead. In the first procedure, Pribil and Matyska[27] propose the use of Complexone III as a volumetric reagent in amperometric analysis. The change in the concentration of an ion may be followed by a dropping mercury electrode to which the correct potential is applied, and, since the complexones form practically undissociated complexes, they are ideal amperometric reagents. The stability of the metal complexes depends on the *p*H of the solution, and this serves to differentiate several metals, in spite of the objection that the complexones are not specific reagents. Three conditions are necessary for amperometric titration with Complexone III.

(*a*) The given cation must form a stable complex sufficiently rapidly.

(*b*) No elements reducible at the dropping mercury electrode at more positive potentials must be present.

(*c*) Any accompanying elements must form less stable complexes than the element to be determined.

For bismuth, ethylenediamine tetra-acetate forms a complexonate stable even at *p*H 1, the complexonates of all bivalent metals being completely dissociated at this *p*H. In practice, the titration is carried out at *p*H 1–2 in nitric acid solution, at an applied potential of −160 to −200 mV, for amounts of bismuth from 2 to 20 mg. The elements lead, zinc, cadmium, chromium, aluminium, arsenic, cobalt and manganese do not interfere. In the presence of antimony^{III}, iron^{III} and nickel, citrate or tartrate must be added to the solutions: these anions form complexes with the aforementioned metals of a greater stability than those with complexone. Silver and copper interfere by their diffusion currents, and tin^{IV} interferes at all concentrations.

The method described is particularly suitable for bismuth in lead or alloys, no preliminary separation

TABLE VIII.—DETERMINATION OF BISMUTH IN LEAD.

Material	Composition—%						Determination No.	Bismuth Found %
	Ag	Cu	Cd	Sb	Fe	Bi		
Bohemian Lead*	0·002	0·002	0·005	0·045	Trace	0·0335	1	0·0585
							2	0·0583
							3	0·0586
							4	0·0584
							5	0·0582
							6	0·0574
							7	0·0578
Soft Lead MR† ..	0·002	0·0057	Trace	0·049	0·005	0·0108	1	0·0190
							2	0·0194
							3	0·0192
							4	0·0188
							5	0·0195
Mexican Lead ..				0·037	0·008	0·023	1	0·035
							2	0·035
							3	0·034
							4	0·034

* Contained traces of Fe, Ni, Co and Zn.
† Contained traces of Cd, Zn and Ni.

being necessary. The sample is dissolved in nitric acid, treated with citrate or tartrate, and the acidity adjusted to pH 2 by ammonia and sodium acetate. An aliquot of the solution is then titrated with a standard solution of Complexone III to constant galvanometer deflection, using gelatin as a maximum suppressor and an applied voltage of -180 to -200 mV on the dropping mercury cathode. In studying the figures quoted in Table VIII it should be noted that the higher figures for the proposed procedure are due to the fact that bismuth in the original analysis was estimated polarographically after precipitation of lead sulphate, on which part of the bismuth probably remained adsorbed.

The second procedure for bismuth, due to Pribil and Cuta[28], is gravimetric in nature and is suitable for the analysis of easily fusible alloys. The addition of calcium ions causes the precipitation of bismuth hydroxide from ammoniacal bismuth solutions. If complexone in the form of its ammonium salt is present, bismuth is quantitatively replaced in the complexonate by calcium, and the bismuth hydroxide is completely free of calcium ions. Bismuth hydroxide is then ignited to bismuth oxide Bi_2O_3. The method is applicable in the presence of lead, so long as chloride ions are not present (these cause lead chloride precipitation), and with copper and cadmium present.

The method was applied to various lead alloys, using 1–25 g. according to the bismuth content. The following points are to be noted.

(1) If no antimony or tin is present, the determination may be carried out by direct precipitation of bismuth hydroxide with ammonia, in the presence of complexone and an equivalent amount of calcium nitrate.

(2) If tin is present, stannic acid must be removed by double evaporation to ensure quantitative precipitation. Metastannic acid is then filtered off and extracted several times with a hot solution of ammonium complexonate to dissolve out any adsorbed cations—this procedure is better than a normal sodium sulphide extraction. Bismuth is then determined as in (1).

(3) Theoretically, the above method can be used for the determination of traces of bismuth in the presence of large amounts of lead, but cannot be put into practice as too much complexone is required. Pribil and Cuta found that bismuth could best be isolated from large amounts of lead by co-precipitation on calomel, bismuth finally being extracted therefrom with hot nitric acid. For traces of bismuth in alloys containing lead but no tin, bismuth is isolated by a suspension of calomel, followed by extraction with nitric acid and, finally, precipitation with ammonia as in (1). In general, the procedure of Pribil and Matyska is preferred for traces of bismuth in lead alloys.

(4) For alloys containing antimony, the same procedure should be followed as for alloys containing tin, i.e., antimonic acid should first be precipitated and then extracted with hot complexone. However, antimonic acid partly dissolves on this treatment, and thus interferes in the determination in the final phase of precipitation with ammonia. It is, therefore, necessary to treat the precipitated bismuth hydroxide, containing antimony, with sodium sulphide. The pure bismuth sulphide produced is ignited to oxide after filtration. Typical results are given in Table IX.

Calcium

Pribil and Fiala[29] have recently completed very important work on the selective determination of calcium but, as yet, the paper has only appeared in Czech. Calcium may be precipitated as oxalate from solutions containing acetic acid and ammonium acetate in the presence of ethylenediamine tetra-acetic acid, and many metals, including iron, zinc and lead, do not then interfere. The method has been applied to the determination of calcium in lead alloys.

A suitable amount of calcium-lead alloy is dissolved in 50 ml. 1:1 nitric acid, evaporated to dryness and diluted to 100 ml. An aliquot is diluted to 100 ml., is mixed with 30–60 ml. of acetic acid, ammonium acetate buffer and excess complexone and the calcium is precipitated with hot 5% ammonium oxalate. The solution is boiled 15–20 minutes, filtered after 3 hours, and the oxalate converted to calcium sulphate. The calcium is then

TABLE IX.—DETERMINATION OF BISMUTH IN LEAD ALLOYS.

Alloy	Composition—%					Procedure	Determination No.	Bismuth Found %
	Pb	Cd	Sn	Sb	Bi			
I	95·83	—	—	—	4·11	1	1	4·20
							2	4·19
							3	4·10
							4	4·20
							5	4·16
							6	4·19
II	93·04	—	—	—	6·96	1	1	6·78
							2	7·08
							3	6·95
							4	6·93
							5	6·84
III	93·93	2·87	—	—	3·20	1	1	3·22
							2	3·24
							3	3·24
							4	3·21
							5	3·15
							6	3·37
IV	95·0	3·42	1·50	—	3·50	2	1	3·56
							2	3·35
							3	3·48
							4	3·58
							5	3·49
V	93·80	2·30	2·20	—	1·70	2	1	1·70
							2	1·71
							3	1·64
							4	1·72
							5	1·70
VI				0·037	0·023	4	1	0·036*
							2	0·034
VII				0·125	0·038	4	1	0·048*
							2	0·049

* Checked amperometrically and found correct. Original values of 0·023% and 0·038% incorrect as they were obtained after isolation of Pb as $PbSO_4$ (adsorption of Bi).

determined by potassium permanganate titration, in the usual way, or by direct titration with Complexone III.

Iron

In the ferrous section of this review, the work of Souchay and Faucherre[7] on the determination of cobalt in steels was described. The same authors describe the determination of traces of iron in the presence of a large excess of copper, which principle has been applied to the determination of small amounts of iron in brasses and in "pure" metals. The iron is initially complexed with ethylenediamine tetra-acetic acid, and a separation of the two waves of iron^{III} and copper is then possible on polarographic reduction; the half-wave potential due to iron is then lowered to $+0{\cdot}125$ volts and that due to copper is $+0{\cdot}4$ volts. The method also permits the simultaneous determination of these two elements—provided that iron is not present in large excess over copper. The waves are well formed and proportional to the concentrations of the two metals, and it is possible to determine iron with excellent precision in the presence of copper in 100-fold greater concentration.

The method is applicable to the determination of iron traces in the presence of metals other than copper, so long as these are deposited at a higher potential than copper. No results are quoted for the actual alloys analysed.

A similar polarographic procedure has been described by Souchay and Faucherre[8] for the analysis of white metals for traces of iron, copper, cadmium, bismuth, nickel and zinc. Here, the principal constituents of the alloys are antimony, lead and tin, containing in one case traces of copper and in the other case about 10% of copper. Complexing with ethylenediamine tetra-acetic acid and potassium citrate separates the iron, copper and bismuth waves in the first case at pH 9, and also iron and copper in the second case at a similar pH. If the iron concentration is much greater than the copper concentration, fluoride is added and the pH adjusted to 5, to permit determination of both copper and iron with ethylenediamine tetra-acetic acid as complexing agent. Bismuth is then separated by reduction to metal and determined separately. After antimony and lead have been removed by volatilisation, an ammonium chloride-ammonia buffer is used to separate the cadmium, nickel and zinc polarographic waves, but in the case of 10% copper a preliminary treatment with potassium iodide is employed for copper removal. Typical polarograms are detailed for all determinations.

Magnesium

Sergeant[30] has recently described in this journal the rapid volumetric estimation of magnesium in aluminium alloys, based on the titration of magnesium with disodium ethylenediamine tetra-acetate, Eriochrome Black T being used as indicator. This author points out that the existing methods for the determination of magnesium in alloys (pyrophosphate, oxine and colorimetric) all have disadvantages, and that a need exists for a rapid method for furnace control work in LM10 alloys containing 9·5–11% of magnesium.

A sodium hydroxide attack on the alloy removes the bulk of aluminium, silicon and zinc. The residues are boiled with dilute sulphuric acid, to free any entrapped magnesium and to obtain the copper in a state of fine division. After filtration, ammonium chloride is first added, followed by bromine, together with ammonia and sodium acetate, to separate manganese by oxidation.

TABLE X.—DETERMINATION OF MANGANESE IN MANGANESE-ALUMINIUM ALLOYS.

Alloy	Composition—%		Determination No.	Manganese Found %
	Al	Mn		
Al_3Mn	56·80	39·25	1	39·09
			2	39·09
			3	39·29

TABLE XI.—DETERMINATION OF SILVER IN SILVER-COPPER.

Alloy	Composition—%		Determination No.	Silver Found %
	Ag	Cu		
I	30	70	1	30·03
			2	29·94
			3	29·97
II	1	99	1	0·982
			2	1·043
			3	0·976

Any iron, chromium and aluminium is also removed in this process. After the addition of more ammonia, any remaining copper or nickel is complexed by potassium cyanide, and the remaining magnesium is titrated complexometrically, as outlined above.

If much silicon is present, a modification is introduced, in that the bulk of the silica is filtered off after an aqua regia attack. A further modification is described for rapid furnace control work. Good results are detailed for alloys containing from 0·32 to 11·76% of magnesium.

Manganese

The procedure of Pribil and Horacek[16] described in the ferrous section of this paper has been applied to the determination of manganese in manganese-aluminium alloys. Table X gives the results of three determinations on such an alloy.

Silver

Dolezal, Hencl and Simon[31] have followed the formation of silver complexonate by potentiometric titration and by polarographic procedure. The effect of pH on the dissociation of silver complexonate is determined polarographically, while silver can actually be titrated potentiometrically according to the following scheme.

To the solution containing at least 1 mg. of silver ion, add 1 ml. of 0·01N complexone and neutralise to bromothymol blue with 0·1N potassium iodide, the end-point being determined potentiometrically. The procedure is satisfactory for silver in the presence of lead, bismuth, copper, cadmium, zinc, arsenic, antimony and iron, although large amounts of antimony and iron have a deleterious effect. Silver may also be determined in the presence of thallium, which combines with complexone in a basic medium. Mercury[11] interferes.

The method has been applied by Dolezal *et al* to the determination of silver in silver-copper alloys and in lead ores. For alloys, the sample is dissolved in nitric acid, treated with tartrate solution to give a final concentration 0·3–0·5M (if antimony is present) and Complexone III added. The pH is brought to 7, using caustic soda, and the resultant solution is titrated with 0·01N potassium iodide as outlined above. Results obtained on two alloys are given in Table XI.

Thallium

Investigations of the polarographic behaviour of thallium[1], copper, lead and iron in Complexone II solutions has shown, according to Pribil and Zabransky,[32]

TABLE XII.—DETERMINATION OF ZINC IN ALUMINIUM ALLOYS

Alloy	Zinc Found in Control Analysis %		Zinc Found %
Aluminium (99·8% purity) ..	0·039	spectrographic	0·040
Aluminium (99·5% purity) ..	0·038	spectrographic	0·040
Aluminium (99% purity) ..	0·032	zinc mercuric thiocyanate	0·031
Aluminium-Copper-Magnesium Alloy	0·14	electrolytic	0·13
	0·14	electrolytic	0·16
	0·14	electrolytic	0·39
	0·14	electrolytic	0·32
	0·14	electrolytic	0·59
Aluminium-Zinc-Magnesium Alloy	4·67	electrolytic	4·71
	4·49	electrolytic	4·50
	4·97	zinc mercuric thiocyanate	4·99
	5·03	zinc mercuric thiocyanate	
	6·06	electrolytic	6·06
	6·78	electrolytic	6·74

that thallium does not form a complex with ethylenediamine tetra-acetic acid in neutral or acid solutions. The occurrence of complex formation in alkaline solution is revealed by a displacement of the half-wave potential of thallium to more negative values. Lead, bismuth and iron^{III} also form complexes in acid solution, with consequent shift of their half-wave potentials to more negative values. Differences in these values permit the distinction of the waves of copper, thallium and lead. On the basis of these observations, thallium traces may be polarographically determined in the presence of lead at pH 4, and in a solution 0·1M with respect to complexone. No results are quoted.

Zinc

The Finnish workers Kinnunen and Merikanto[33] have published interesting data concerning the volumetric complexometric determination of zinc in metallurgical products. They detail four procedures, all of which are based finally on the titration of zinc at pH 10 with a standard disodium ethylenediamine tetra-acetate solution, using Eriochrome Black T as indicator.

Procedure I is suitable for commercial zinc concentrates, and is based on the separation of zinc as zinc sulphide, after initial removal of copper. Zinc sulphide is then dissolved in hydrochloric acid, suitably buffered with ammonia and ammonium chloride solution, and titrated with Complexone III to the sharp change from red to blue. The whole procedure takes about 3–4 hours.

Procedure II is satisfactory for the determination of zinc in the presence of copper, e.g., in brass, without any preceding separation. Both zinc and copper are complexed to form their complex cyanides with potassium cyanide in ammoniacal solution. The zinc cyanide complex is, however, less stable than that of copper, and free zinc ions may be liberated from the cyanide complex by means of formaldehyde, the copper complex remaining unchanged. The zinc is then titrated as above, the whole determination taking six minutes.

Procedure III is utilised for the determination of zinc in gun metal. When large amounts of copper cyanide are present (as would be the case if Procedure II were followed with gun metal) the end point is often poor or fails completely. It is, therefore, desirable to remove most of the copper by displacement from solution with aluminium, or by electrolysis in a chloride solution, before applying the cyanide technique.

Procedure IV is similar to that under III, and can be used for routine estimations with zinc concentrates, in place of the longer Procedure I, if the amounts of cadmium, lime, calcium and magnesium are low, or can be regarded as constant.

In a further communication concerning the determination of zinc in metallurgical products, Kinnunen and Wennerstrand[34] describe the extraction of zinc thiocyanate with methyl isobutyl ketone solvent. This extraction is quantitative in a single extraction, only traces of zinc remaining in the aqueous phase under specified conditions of acidity, presence of foreign salts, concentration of thiocyanate, and relative volumes of solvent and water phases.

The method is described in its application to zinc concentrates. After decomposition of the sample with nitric acid and bromine, the filtered solution is neutralised with ammonia and then ammonium hydrogen fluoride, thiourea and ammonium thiocyanate are added in turn. The solution is extracted with methyl isobutyl ketone and the organic layer treated with buffer solution, acetone and finally diluted with water. Potassium cyanide is added to complex the zinc, and the whole is titrated with Complexone III solution, using Eriochrome Black T as indicator, until a blue colour is reached. Small increments of formaldehyde are added, and titration is continued till further addition of formalin does not further affect the end-point.

Good results are detailed for the determination of zinc in zinc concentrates, zinc ore, zinc tailings, copper concentrates, copper slag, copper matt, lead concentrates, brass, gun metal, tin bronze and German silver, in concentrations ranging from 0·63% to 50·0% of zinc. The time involved for most samples is less than 20 minutes.

A procedure for the rapid complexometric determination of zinc in aluminium and aluminium alloys is presented by Faller.[35] This depends on the isolation of zinc as the sulphide, and its subsequent determination by titration with Complexone III and Eriochrome Black T as indicator. The sample is dissolved in caustic soda solution, hydrazine sulphate added, and the solution boiled and filtered. Zinc is precipitated in the filtrate with sodium sulphide solution, which is filtered off, washed with hot sodium sulphide solution, and then dissolved in hydrochloric acid. Citric acid and ammonia are added, and the zinc ions are then titrated at 30° C. at pH 8·5–9·5. This method is applicable for 0·002–0·2% of zinc, in pure aluminium and alloys containing only small amounts of copper, iron, and manganese. The accuracy is ± 0·002–0·005% and the procedure takes 50 minutes.

Faller proposes a slight modification for alloys containing from 0·1 to 8·0% zinc. Here the accuracy is ± 0·001–0·05% and the method takes 40 minutes. In the case of alloys containing about 2% copper, and up to 8% of zinc, an alternative dissolution procedure is detailed which gives good results but takes somewhat longer. Faller quotes the results set out in Table XII.

Flaschka[36] points out that zinc is often determined in aluminium or light metal alloys by precipitation as zinc mercuric thiocyanate $ZnHg(SCN)_4$ with mercuric thiocyanate. This compound can be titrated with disodium ethylenediamine tetra-acetate. Either the zinc in the precipitate alone, or both the zinc and the mercury can be titrated. For the titration of zinc alone, the precipitate can be dissolved in a solution of potassium iodide, whereby the mercury is converted to the complex $(HgI_4)^{-2}$ which is stronger than mercury complexonate.

The mercury is thus masked and zinc is titrated in the usual way.

Another possibility is to dissolve the precipitate in potassium cyanide. Zinc is then liberated by addition of formaldehyde or chloral hydrate and titrated with Complexone III. This procedure is superior if any traces of copper, nickel, cobalt, iron or heavy metals are co-precipitated with the zinc. Usually these metals affect the indicator. They are masked with potassium cyanide and their complexes are not affected by the aldehydes.

Yet a third possibility is to dissolve the precipitate in an excess of complexone solution, and to back-titrate with zinc sulphate solution. In this way, both zinc and mercury are determined. Flaschka presents results for all three methods.

Miscellaneous

Flaschka[37] has described the specific complexometric volumetric determination of zinc and cadmium in the presence of cobalt, nickel, copper and mercury. All metals are converted into their complex cyanides by means of potassium cyanide; of the metals mentioned, only zinc and cadmium can now be decomposed into their free ions by means of formaldehyde, with subsequent titration with Complexone III and Eriochrome Black T as indicator. It is also possible to determine calcium, magnesium and lead on the same sample. Flaschka has suggested that the method can be applied to various alloys, for instance, zinc and copper together, but does not give details.

Schwarzenbach[38] has proposed an application of complexometric titration in steel analysis. $Iron^{III}$ may be titrated in acid solution (pH 2–3) with Complexone III solution, using Tiron (disodium pyrocatechol 3 : 5-disulphonate) as indicator. When all the iron is complexed, the iron is present as an anion, and may then be separated from other metals present by running the solution through an ion-exchange resin. Schwarzenbach proposed this procedure for the separation of iron during the analysis of steels and other iron alloys.

Conclusions

Much of the work of Pribil and his school on the analytical applications of the complexones is undoubtedly capable of application to metallurgical analysis, although in this review, mention has only been made of the specific proposals of the Czechoslovak workers in this connection. For instance, papers on the metallurgically important elements tungsten, titanium, and aluminium have also appeared. Again, much of the work of Pribil has as yet only appeared in the Czech journal "Chemicke Listy" and awaits appearance in English in the "Collection of Czechoslovak Chemical Communications." One reason for the apparent neglect of these compounds in analysis is lack of knowledge of the existence of Pribil's work in English, but it should be pointed out that these papers are available from several sources in this country. For complete experimental details, the original articles referred to in this review should, of course, be consulted, but enough has been given to show that a fruitful field in metallurgical analysis has been opened up. It is to be expected that the complexones will gain the importance in this field of analysis that they have achieved in other spheres, particularly water analysis.

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Commercial Vacuum-Melted High Temperature Alloys

VACUUM METALS CORPORATION of Cambridge, Mass., U.S.A., is starting the first commercial production of vacuum melted high temperature alloys, and is expanding production of high purity nickel alloys for electronic tube construction. The continued high interest in Ferrovac-52100, a vacuum melted low-alloy steel, promises an increasing demand for this product in 1954. Vacuum Metals Corporation, a wholly owned subsidiary of National Research Corporation, and the first and only commercial source for vacuum melted alloys in the United States, has been engaged in the development of new metallurgical processes for the past ten years.

As a result of several years of research work, the interest in vacuum melted, high temperature alloys has been mounting rapidly. The research work begun in 1946 at Vacuum Metals Corporation has now borne fruit in the receipt of the first commercial quantity orders from jet engine manufacturers. The application of this vacuum melted product gives promise of not only better performance of the alloy in the engine, but also increased ease of fabrication and higher yields. Since one of the principal obstacles in the way of continued improvement in gas turbine performance is the requirement for materials with improved high temperature properties, this development is of considerable importance.

During the past year there has been a continual increase in interest in vacuum melted high purity nickel, copper and iron, and dilute alloys of these metals for electronic tube components. In the first half of 1954, some of the alloys which have been hitherto produced on an experimental basis are being standardised for commercial production. Production tests have demonstrated very substantial increases in manufacturing yields of electronic tubes through the utilisation of certain of these alloys. For this application, vacuum melting permits the precise control of very dilute alloying additions, as well as of trace impurities, to give tubes of improved dependability and performance.

During the past six-month period, many tons of Ferrovac-52100 steel have been produced for manufacturers of high quality ball bearings. Decreased production costs of precision bearings through a higher manufacturing yield have resulted from the use of this vacuum refined steel, which has greatly improved cleanliness and freedom from gas. Numerous field tests of various types of bearings are in process, and reports from several sources have indicated a two-and three-fold increase in the life of bearing balls made from this steel. Other vacuum melted alloy steels for applications requiring high fatigue strength are under test by manufacturers.

The B.I.S.R.A. Photo-Electric Dust Meter

Continuous Recorder Based on Light Scattering

THE cleanliness of blast furnace gas is an important factor in the operational efficiency of any steel works plant. In the event of dust suspended in the gas reaching the coke oven battery, there is a marked tendency for the particles to form a deposit which sinters and produces an insulating layer on the refractory brickwork, preventing efficient heat transference from the firing chamber to the coking oven. In addition, continued dust deposition can cause eventual blockage of the path taken by the gases through the refractory, and this sometimes necessitates complete re-bricking of this part of the installation.

Although measurement of the dust concentration by gravimetric methods is accurate, it must necessarily take place after passage of the particles through the plant. Thus, it is impossible to determine by this means whether a uniform dust concentration has existed over the set measuring period, or whether the deposit has been caused by a few short periods of high dust concentration, resulting from intermittent failure or overloading of some sections of the cleaning plant. This has been overcome by a continuously recording instrument, developed by B.I.S.R.A. and manufactured by Radiovisor Parent, Ltd., which monitors the gases at any chosen point in the main ; it may be calibrated in conjunction with standard gravimetric measurements, and to suit site conditions. The equipment enables an alarm to be sounded immediately a pre-determined dust level is exceeded, and it also provides a continuous record of the dust concentration and its variations.

The instrument comprises four main components :—

(1) The sampling chamber, in which are installed photo-electric cells, the light source, and an optical system.

(2) A thermionic valve amplifier, together with its stabiliser, power supplies, and setting-up controls.

(3) A 7-inch diameter indicator-relay meter incorporating a small contactor for connection to an alarm system.

(4) A continuous $3\frac{1}{2}$ in. wide strip recorder.

Principle of Operation

The light source and optical system in the sampling chamber gives a parallel beam of light of uniform intensity, which is projected through the actual viewing chamber on to a light trap specially designed to prevent secondary light radiation. The viewing chamber consists of a series of baffles to maintain the cylinder of light, and a glass cylinder with gas-tight joints ; on the outside of the cylinder are three photo-multiplier cells. The complete unit is suitably insulated to reduce heat losses.

The output leads from the photo-multiplier cells and the high-tension and projector lamp supplies are brought to a multi-point insulated plug, from which a flexible cable is taken to the electronic control panel. This incorporates thermionic valve amplifiers and their associated power supplies : care is taken to ensure the maintenance of a consistent supply for the H.T. and L.T. voltage feeds. Controls are provided for setting the instrument to zero, and the meters are suitably graduated to indicate the necessary circuit characteristics. The output lead from the panel is taken to a 7 in. diameter flush-mounted meter provided with a small contactor to operate the alarm. This is energised by setting an auxiliary pointer on the instrument dial to a pre-determined reading, and when the indicator needle coincides with this point a circuit to the contactor control coil is completed.

This instrument works on the "light-scattering" technique. Thus, by introducing clean air into the viewing chamber, a minimum of light scatter takes place, and a minimum current is passed by the photocells. The output from the electronic amplifier is "backed off," so that in this condition a zero reading is shown on the recorder and meter. Any increase in light scatter due to dust particles suspended in the gas results in an increase in the photomultiplier current, with a corresponding deflection of the needle of the indicator meter.

Mode of Operation

In use, the blast-furnace gas is taken from the main, raised above dew point by pre-heating it with steam coils, and fed through the viewing chamber. After recording the dust concentration it is then either injected back into the gas main by an impeller, or exhausted to atmosphere. To prevent aggregation of the particles, the design of the sampling tube incorporates smooth bends, gate-type valves, and a thin-walled receiving tube. Gas velocities in the main stream are measured, and the flow rate in the sampling by-pass controlled, by an orifice plate : this ensures that a correct comparative reading of the dust concentration is obtained.

The equipment has undergone prolonged trials under the guidance of the British Iron and Steel Research Association at various steel works, and the figures obtained proved consistent when checked by gravimetric estimates. The results showed sharp increases in dust concentration when part of the cleaning plant was closed down.

B.I.S.R.A. "3-D" Films

THE high-speed stereoscopic films shown by B.I.S.R.A. at the Seventh International Festival of Science Films in London last September aroused such interest that the scientists responsible were invited to present them at the International Festival of Industrial Films organised in Belgium by the Cinématheque de Belgique. The films show in slow motion and three dimensions the interior of a blast furnace seen through a tuyere. Using apparatus designed and built in B.I.S.R.A.'s Physics Laboratories, Mr. Charles Burns showed them with explanatory lectures in French at three meetings of the Festival in Brussels, Liège and Charleroi in January. They evoked great interest and some well-informed discussion. After this, Mr. Burns was able to give an impromptu demonstration at the Royal Dutch Blast Furnaces and Iron Works in Ijmuiden, thanks to the interest and efforts of the Director of the Research Department and the Director of the Netherlands Technical Film Centre.